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ENVIRONMENTAL GUIDELINES FOR DEVELOPMENT ROADS IN THE SUBARCTIC

Frederick B. Lotspeich, et al

Alaska University

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This set of guidelines is based on Federal and State regulations that set standards to protect the total environment. Although major highway construction is under stringent regulation, pioneer type access roads such as are needed by loggers, miners, land developers, etc., have been neglected. These smaller roads frequently pose serious erosion hazards because planning, design, and construction of them is not thorough, as it is for major roads; this results in erosion, fire and insect traps, and generally unattractive roadways.

Suggestions and recommendations contained in these guidelines are for the use of operators with limited engineering and planning staffs. Although all examples of poor practices are from the vicinity of Fairbanks, all suggested treatments are taken from the literature from the conterminous United States with some modifications for subarctic conditions. Most of these recommendations are simple in concept, and if properly applied, do prevent erosion and result in superior access roads which are esthetically pleasing. (EPA)

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EPA-660/3-74-009
June 1974

ENVIRONMENTAL GUIDELINES
FOR
DEVELOPMENT ROADS IN THE SUBARCTIC

by

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Corvallis, Oregon 97330

ABSTRACT

This set of guidelines is based on Federal and State regulations that set standards to protect the total environment. Although major highway construction is under stringent regulation, pioneer type access roads such as are needed by loggers, miners, land developers, etc. have been neglected. These smaller roads frequently pose serious erosion hazards because planning, design, and construction of them is not thorough, as it is for major roads; this results in erosion, fire and insect traps, and generally unattractive roadways.

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PREFACE

"Environmental Guidelines for Road Construction in Alaska," by Dr. Frederick B. Lotspeich, was published in 1971 to "...describe the best practical measures required to assure environmental protection during road construction under cold climate conditions." The report that follows has a similar purpose, but with particular emphasis on logging and other pioneer type development roads.

This report is essentially a collection of guidelines that, it is hoped, will serve to emphasize the need to consider road planning at the same time that resource developments are planned. The suggestions provided here are not based on research in Alaska. Instead, they are an amalgam of observations, ideas, and recommendations from a number of people involved in timber sales, zoning and planning, and land management; intended to be a helpful guide until definitive road standards for Alaskan conditions can be developed through research and experience.

The authors hope that resource managers and timber sale administrators alike will share ideas for improved access road construction and maintenance--in the interest of beneficial resource use while maintaining a quality environment for all other resource uses.

CONCLUSIONS

Ecological systems in the subarctic characteristically are in a state of delicate balance. Small changes in one environment can profoundly affect many other factors, and for a long time. Accordingly, disturbances such as pioneer access roads, common to most rapidly developing areas, must be carefully planned to prevent undesirable environmental damage. In the sensitive ecosystems of the subarctic, such damage can be of large scale, far-reaching in its effects, and sometimes virtually irreversible. Key points in access road design, construction, and maintenance relate to site and road drainage, to right-of-way clearing, and to maintenance:

1. Road planning should include consideration of long-range area management objectives, and should take advantage of planning tools such as maps, aerial photography, and engineering advice.

2. Permafrost should be avoided, or crossed high on slopes, where bedrock is near the mantle surface.

3. Right-of-way timber should be cut close to the ground, into the right-of-way, and away from streams. The surface material disturbance caused by bulldozers can be avoided with hand clearing. The cleared width should be a minimum. The organic mat should be undisturbed, if possible. This is very important over muskegs and permafrost, where the cleared material also should be placed under the fill. Heavy equipment should be kept off the right-of-way.

4. Proper drainage is one of the most important factors. Design an outsloped roadway, if possible, consistent with loads to be moved. If drain ditches must be used, runoff should be intercepted at frequent intervals to avoid build-up of erosive power. Runoff should be carried across the road to stable slopes. Designs such as open-tops, rolled grades, cross drains, or shallow ditches usually are suitable drainage structures.

5. The road should be maintained during use, to preserve adequate drainage, and thus to reduce erosion and sedimentation.

6. Wood and culverts should be removed when road use is finished. Open-tops should be removed and replaced with gravel cross drains. Erodible areas should be stabilized by planting and fertilizing.

INTRODUCTION

OBJECTIVES

In 1971 "Environmental Guidelines for Road Construction in Alaska," by Dr. Frederick B. Lotspeich, was published to "...describe the best practical measures required to assure environmental protection during road construction under cold climate conditions." The report that follows has a similar purpose.

The objectives of these guidelines are to collect, compile, and make available to resource managers and operators, and to others who need development roads in the subarctic, the methods, procedures, and engineering principles that will permit road access with minimum damage to the resource base. The principal aim is to focus on unique problems associated with the cold-dominated environment as they would influence access road building. An ancillary purpose is to distribute such information to other segments of the public to inform them about acceptable pioneer road practices and why and how such activities can be performed without undue damage to the environment.

SCOPE

This report is a collection and summary of road related practices, with emphasis on resource development roads which meet environmental protection requirements. Many acceptable practices in warmer climates can be used where permafrost occurs if proper restrictions or modifications are used to prevent unwanted thawing and thermal erosion. It is not enough to prevent erosion as a soils-saving measure; it also must be controlled to prevent water degradation by sedimentation.

Engineering efforts associated with pioneer road construction are usually minimal because many developments are small. This guide contains--and refers to--engineering experience, procedures, and criteria to assist the small operator in applying sound procedures to route selection and to building pioneer access roads.

The suggestions provided here are not based on our research in the subarctic. Instead, they are an amalgam of observations, ideas, and recommendations from a number of people involved in timber sales, zoning and planning, and land management; and are intended to be a guide until definitive road standards for northern conditions can be developed through research and experience. The authors hope that resource managers, timber sale administrators, miners, and contractors alike will share ideas for improved access road construction and maintenance--in the interest of beneficial resource use while maintaining a quality environment.

THE SUBSTRATE

All of interior Alaska is within the zone of discontinuous permafrost. Many south slopes and valley areas are frost-free, but many low-lying areas and all colder slopes are underlain by discontinuous to continuous permafrost. Roads built on such terrain may be unusable during the summer season and can erode rapidly.

Mature forests have a well-developed duff layer that adequately protects the soils from erosion if undisturbed. However, logging, mining, and subdivision development, with their associated road building, uncover the mineral soil by removing the organic layer and expose the poorly aggregated soil to water erosion. Most of these operations are small and isolated from public view, and erosion may be active during and following a development operation unless corrective steps are taken. Land subdivision access roads are exposed to view but often with no erosion prevention practices (Figures 1 and 2).

RECENT FEDERAL LEGISLATION

Water pollution legislation before 1965 was largely ineffectual and emphasized water supply and sewage treatment. The Water Quality Act of 1965 created a new organization within the Department of Health, Education, and Welfare devoted to pollution control and set up a system for state water quality standards subject to Federal approval. The Act of 1965 amended the Act of 1956 and also provided for research and made funds available through grants for construction of treatment plants and demonstration projects. This organization was transferred to the Department of the Interior in 1966.

In 1966 the Clean Water Restoration Act was passed, which emphasized the need for immediate cleanup with provisions for Federal assistance to municipalities in funding treatment plants. The Water Quality Improvement Act was passed by Congress in 1970, which strengthened the previous laws. A complete reorganization of a number of agencies in the Executive Branch having environmental responsibilities was accomplished in 1970, with the formation of the Environmental Protection Agency. This reorganization placed the responsibility for most environmental activities within one agency and includes water, air, solid waste, radiation, pesticides, and noise pollution.

The Federal Water Pollution Control Act of 1972 includes water controls and sets dates for compliance to standards.

These actions by Congress and the President were in response to a growing awareness that environmental damage is severe and that preventive measures are urgently needed. It also indicates that an informed, articulate public recognizes that the environment is composed of many interrelated, interacting elements that must be treated as a system instead of individual elements.

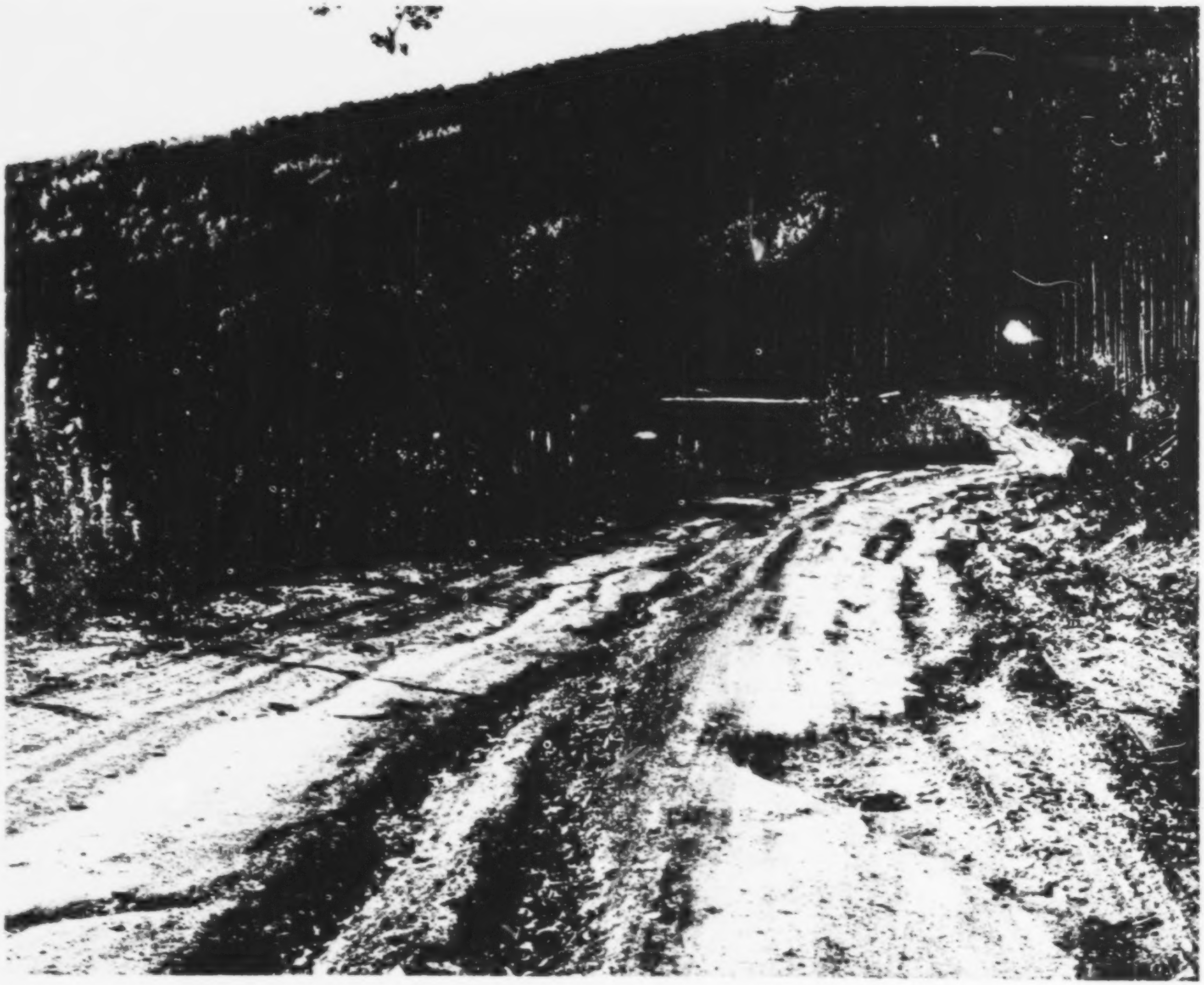

Figure 1. An access road for a private subdivision a few miles north of Fairbanks. Two serious deficiencies are evident in this photo: no effort at proper drainage and no road maintenance, even though this photo was taken near the end of the summer in 1973.

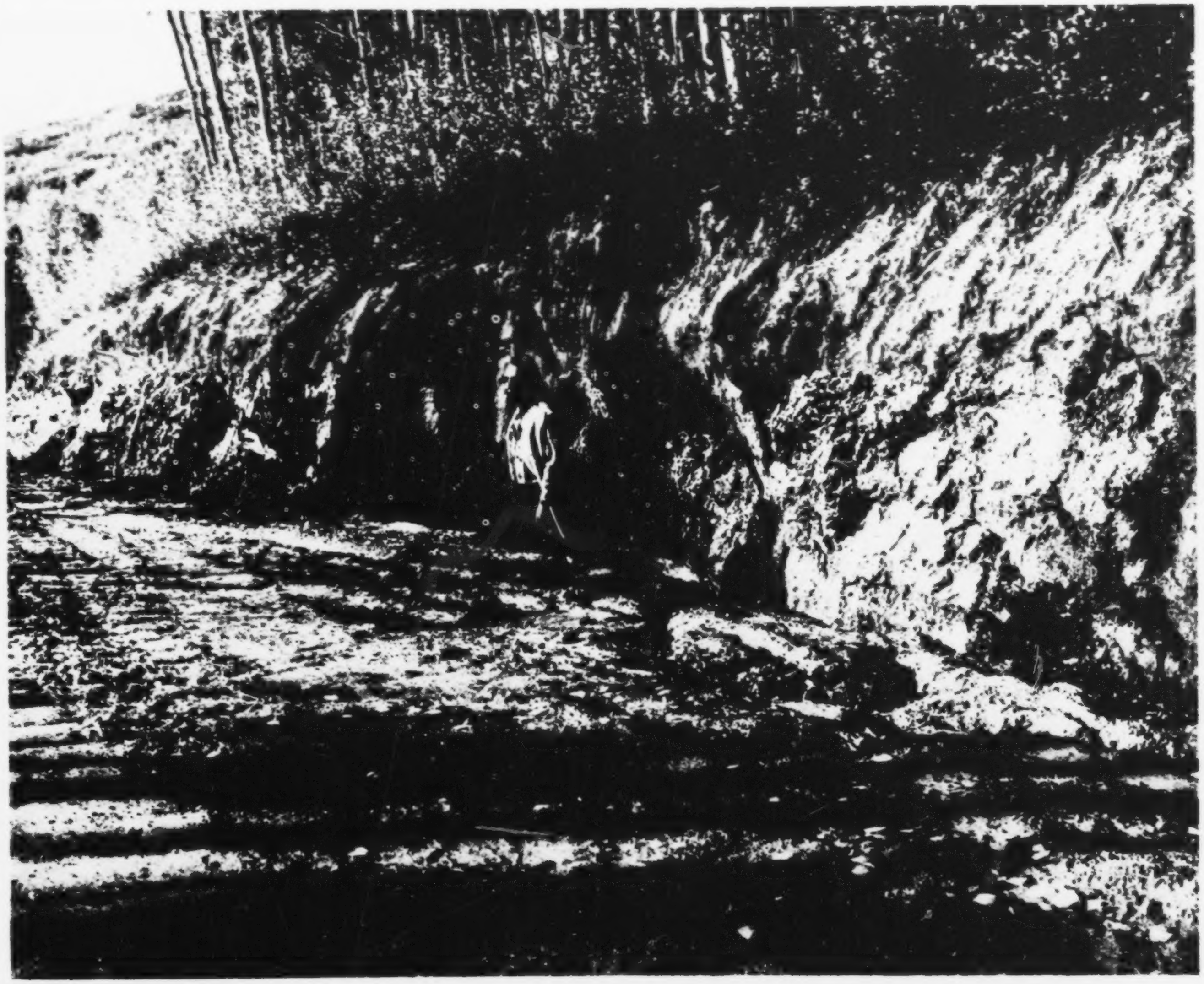

Figure 2. Another example of erosion of a roadside ditch on another private subdivision off Steele Creek Road north of Fairbanks. Proper drainage would have prevented this unsightly gully from forming.

The National Environmental Policy Act of 1969 (NEPA), while not directly emphasizing pollution, states the broad objectives of our national policy toward the environment and establishes a permanent Council on Environmental Quality. A very important provision of the NEPA is the requirement that if any major action by a Federal agency is likely to significantly affect the environment, the agency shall prepare a detailed statement on the impact of this action. Moreover, it includes the stipulation that major action of other organizations supported by Federal funds shall also require an environmental impact statement. Thus, it becomes apparent that a large percentage of proposed activities require environmental impact statements, either because it is a direct Federal activity or is federally funded.

Since most of man's activities disrupt the environment to some degree, any planned action should be conducted with forethought toward minimizing this damage. Various measures to implement, regulate, and set standards are mentioned in the cited Acts. What now remains to be accomplished is to devise, with these tools, the methods, guidelines, and procedures that will accomplish the task without undue impediment to operators. This can best be done when the individuals responsible are convinced that the environmental way is the preferred way and that regulations are not intended to restrict, but to expedite, a better way of life for all, now and in the future.

With the new public awareness of the need for environmental protection, an increasing number of road construction contracts probably will include stipulations and recommended procedures to prevent erosion damage to water and soil resources.

PLANNING AND ROUTE SELECTION

Planning for a development operation must consider the long-range management goals, because these goals will influence road layout. A logging contract, for example, should include a brief statement of management policies. Early mention of these will prevent misunderstanding and help to achieve the proper resource management. Plans for harvesting small timber stands adjacent to access roads (Figures 3, 4, and 5) may not require more than a few notes. More complex, longer-term logging or land development operations require detailed road layouts as part of the contract, or plan, to avoid confusion and comply with environmental requirements. The Industrial Waste Guide on Logging Practices (FWPCA 1970) contains many suggestions on timber harvesting which can be applied to Alaska.

Both aerial photos and topographic maps are useful in planning road layouts, with all routes checked by ground reconnaissance. This last step is important and will pay off in avoiding problem areas that do not appear on maps. The complete road net should be planned systematically instead of one step at a time; it has been shown that haphazard road planning results in more mileage and greater damage from erosion and sedimentation.

Areas having soils that are susceptible to slides and slumps, excessive settlement, severe erosion, and soil creep should be avoided wherever possible. Areas of permafrost should be avoided if at all possible, and alternate routes explored even if some additional distances are involved. A short section of thawing permafrost may cause serious maintenance problems, damage to resources, and increased operating costs. Generally the costs of building on sloping, frozen ground, and the attendant damages, outweigh most benefits. When the resource to be used is located on slopes, the main roads should be located as far upslope as possible. There the soils usually are shallow over bedrock and/or more resistant to erosion. North slopes should be avoided since most of these exposures are frozen, even near the ridge crests. Intensive thermal, or permafrost, reconnaissance may show that some north slopes can be used for roads near the crests if bedrock is near the surface.

A completed route map based on map and ground reconnaissance should accompany any contract application and be approved before cutting or construction commences. This route map need not be based on a sophisticated survey; frequently an Abney level traverse is sufficient, but grades, drainage, and borrow areas should be clearly indicated. In locating roads, consideration must be made of the equipment which will use them, and sufficient radius allowed on turns to accomodate the longest vehicle. Long steady grades are to be avoided; if they are present, they should be broken with short sections of level or reverse grades. These measures prevent the accumulation of excess drainage water at points likely to erode and permit wider distribution of runoff with concentrations at only a few points.

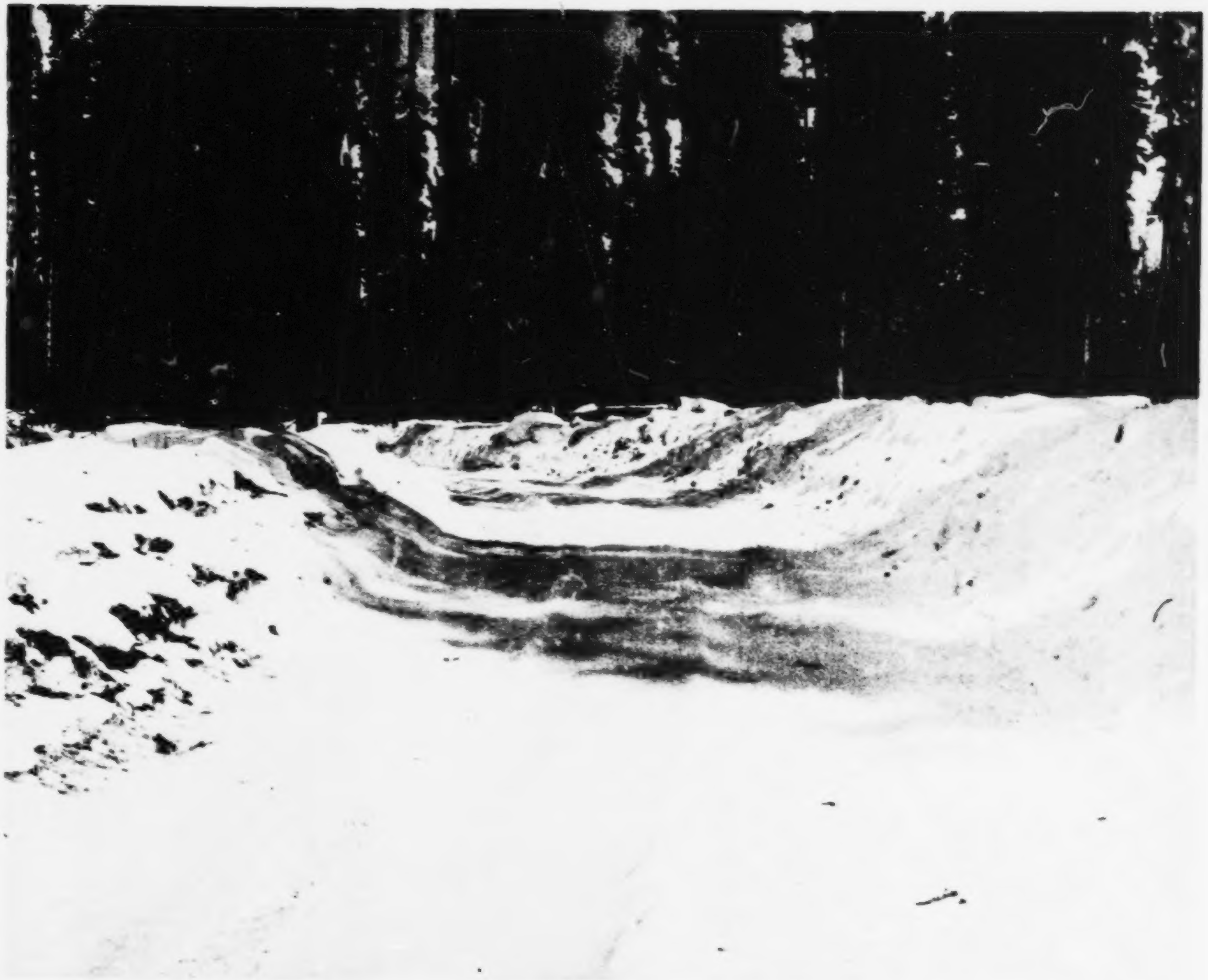

Figure 3. Winter haul road on a flood plain. Such a road requires minimum engineering and construction effort. Erosion is minor, even without treatments, because the terrain is

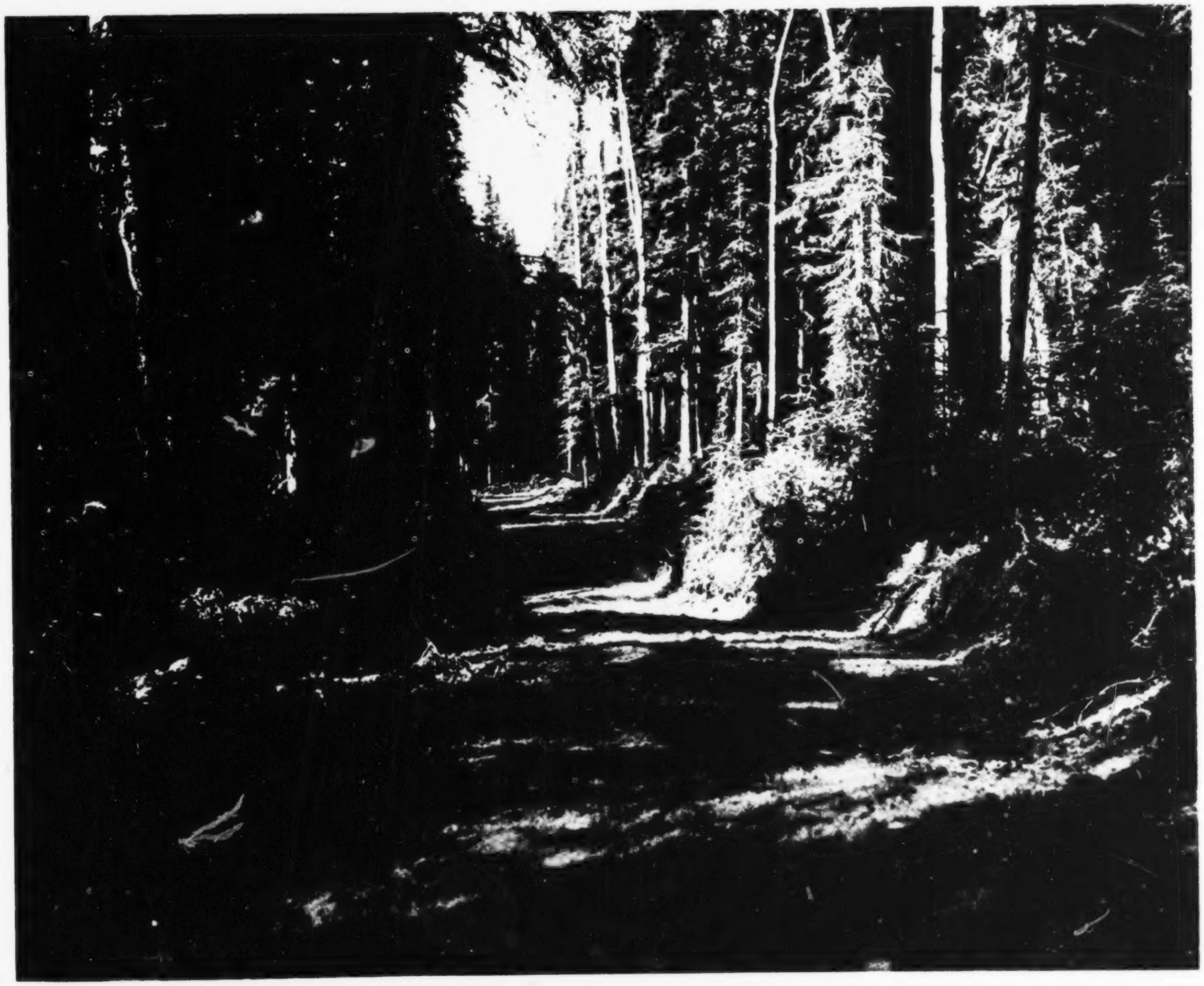

Figure 4. Summer log haul road traversing a 10-20 percent slope. It is an example of adequate right-of-way clearing and of construction standard for winter or dry weather hauling. (Bonanza Creek Experimental Forest, west of Fairbanks)

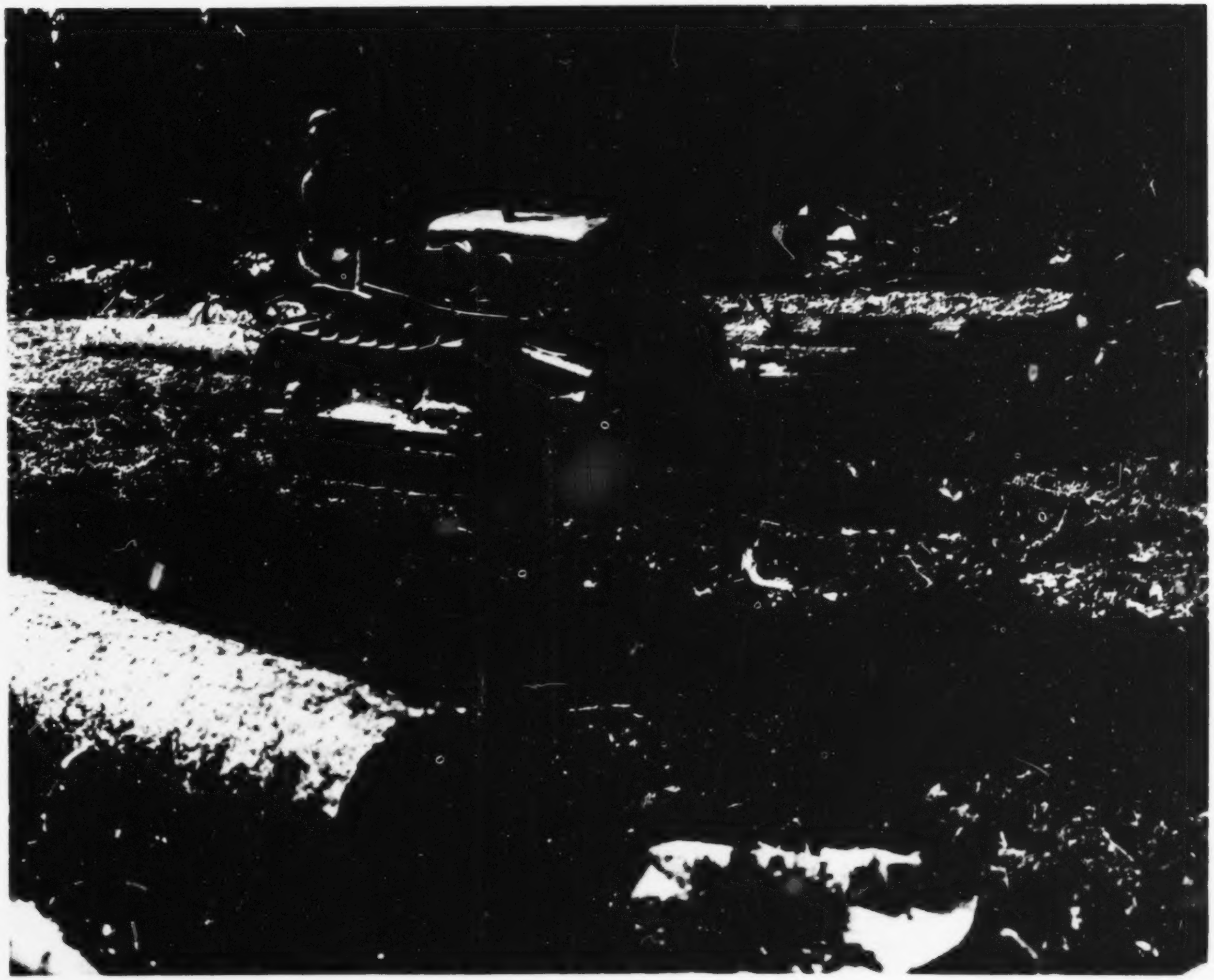

Figure 5. Late winter short log yarding in a flood plain forest. Keeping yarding distance to a minimum results in more distance in truck trails. Compensation occurs through short logs, smaller loads, and winter logging. The significance of yarding distance is due to lodgement of alluvial silts in the bark of logs, and consequent rapid saw wear. Winter logging reduces the silt load, but even wind deposited silts are a problem. (Gerstle River)

Each operation or development will be unique, and protective measures must be located and designed for each project or contract. Also included in the plan should be descriptions of protective measures to be accomplished to avoid erosion and unnecessary disturbance of the soil.

ROAD DESIGN

Several factors control the design of access roads. A well-selected route will avoid obvious problem areas, although some unforeseen problems may arise. Design of a road located far from problem areas is routine, because natural drainage characteristics can be determined from maps, and proper drainage structures can be engineered to provide for disposal of water. Field observations show that the most serious oversight in planning access roads is inadequate drainage. Melt and rain water must not be permitted to accumulate in bar ditches or on the roadway. However, even the best route may have sections requiring special designs.

Projected loads, size of the operation, and anticipated use of the road all influence ultimate design. The road should be designed with these in mind and extra attention given to problem areas because all portions of the road must meet the same load requirements. Long-log hauling with "semi's," for example, will have different curve requirements than will short-log hauling. Small operations with few vehicles may not need a two-way road; one with many vehicles may require wide roads or many turnouts for passing. Design specifications should be apparent in the contract and resource management plan.

Final disposition of the road after the development is completed must be considered; is it to be put to bed, or will it remain in use, for example, as public access to new recreation areas.

ROAD PRISM AND GRADIENT

Although gradient is controlled by location and topography, local variations should consider drainage structure requirements.

1. Have fill slopes with less gradient than the angle of repose for the given material.

2. Design a gentle outslope on roads that do not have inner drainage ditches (Figures 6, 7, 8, 9, 10, and 11). Outsloping permits drainage of melt water over the outside edge of the roadway without channelling parallel to the roadway. On cut and fill in wind-deposited silts, design vertical cuts, intercept runoff above the cuts and conduct it to natural drainageways that provide adequate erosion protection. Figure 12 shows a potentially dangerous, but in this case, successful design. Figure 13 shows a water diversion successful for entrenched roads, such as shown in Figure 12.

3. Keep grades to less than 6 percent, except for short distances where as high as 10 percent may be allowed for unusual conditions, such as entering a natural drainage.

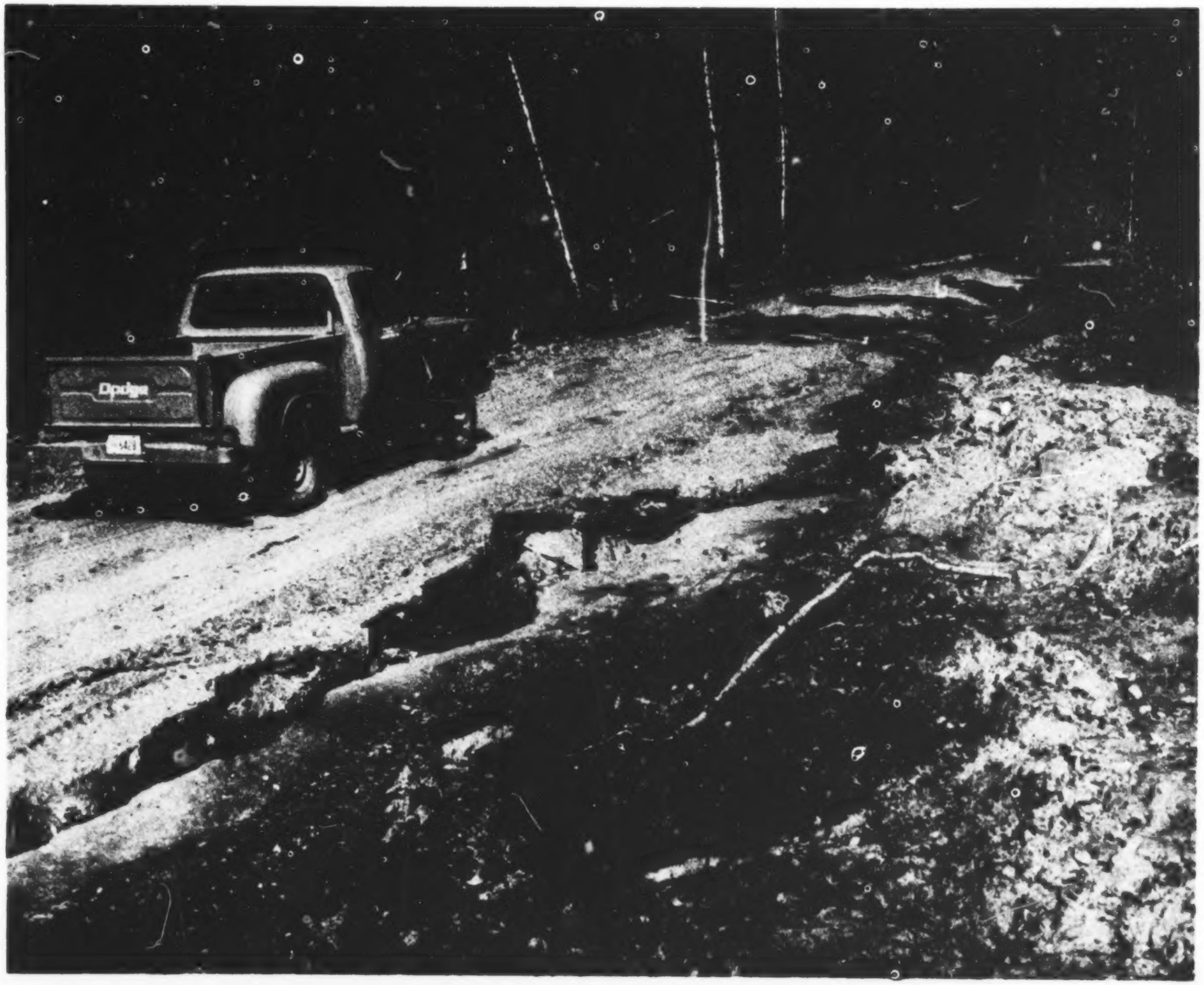

Figure 6. Erosion of this log haul road was rapid despite the gravel content of the soil--runoff from spring breakup was concentrated on the inner edge of the road. Cross drainage is needed. Near Fairbanks, Alaska.

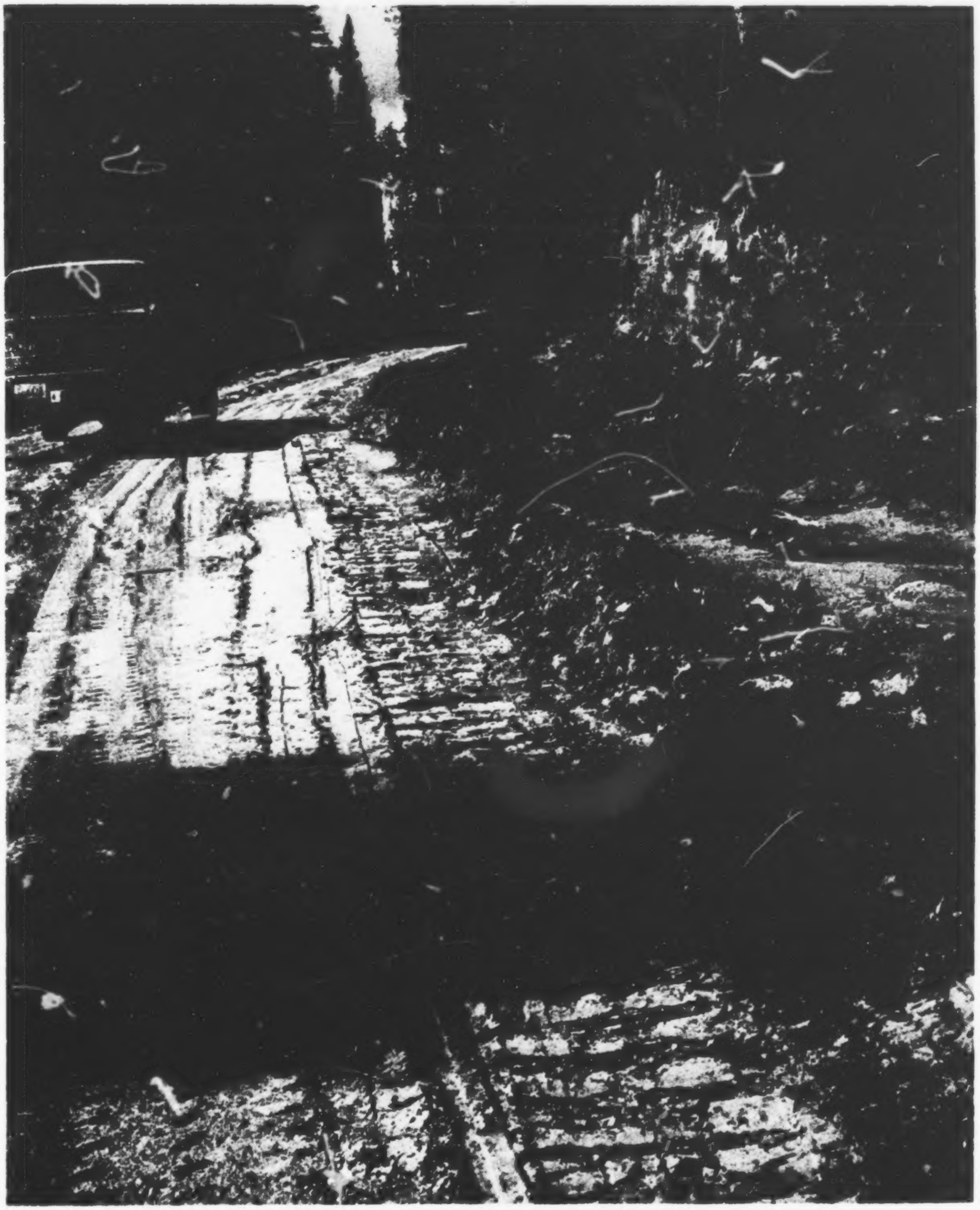

Figure 7. Erosion in silt soil; same road as in Figure 6. Cross drainage would have prevented the gully. Near Fairbanks, Alaska.

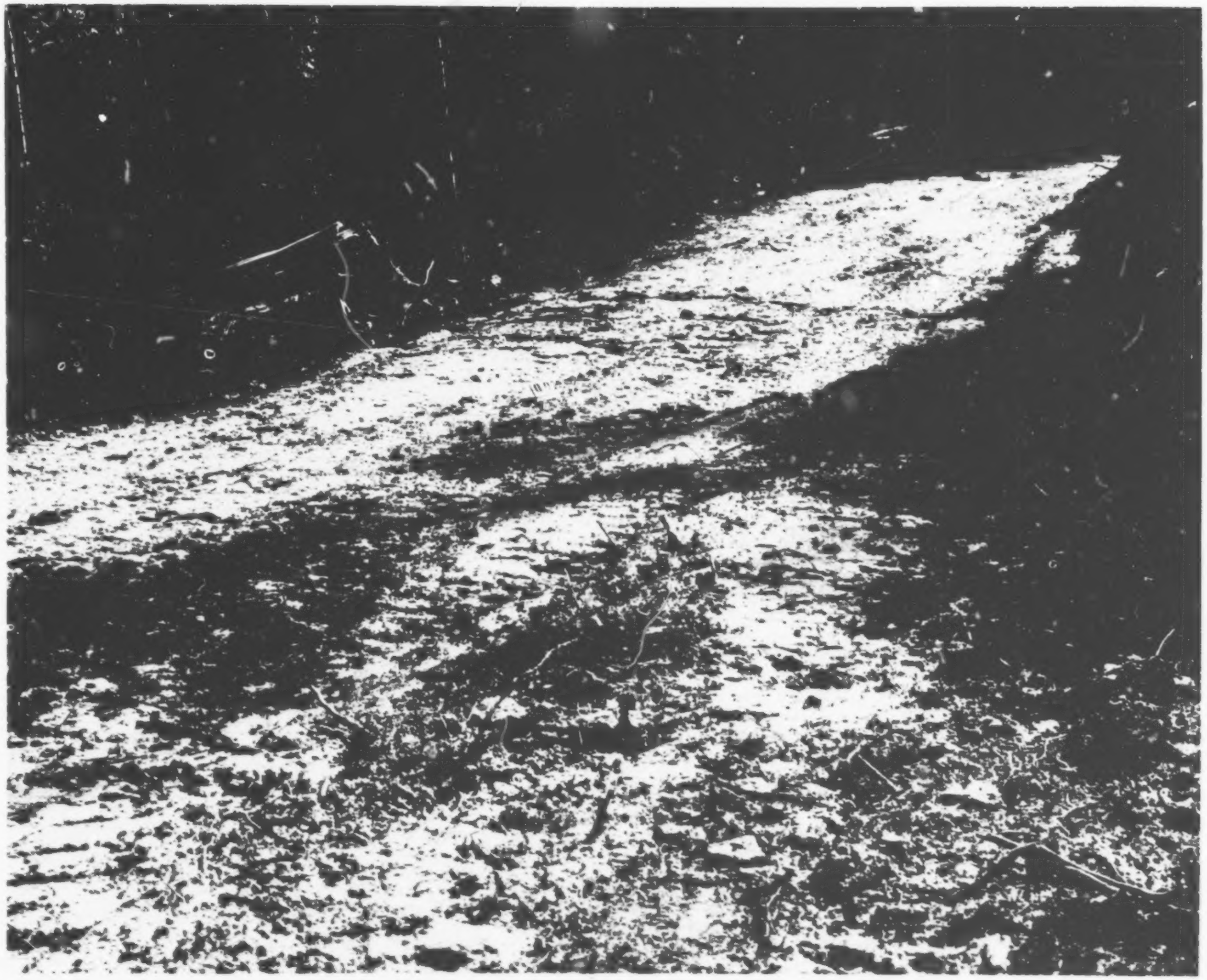

Figure 8. Cross drainage by outsloping. Slight rilling shows that the outslope gradient is more than is needed. However, no sediment was transported beyond the road clearing. Near Fairbanks, Alaska.

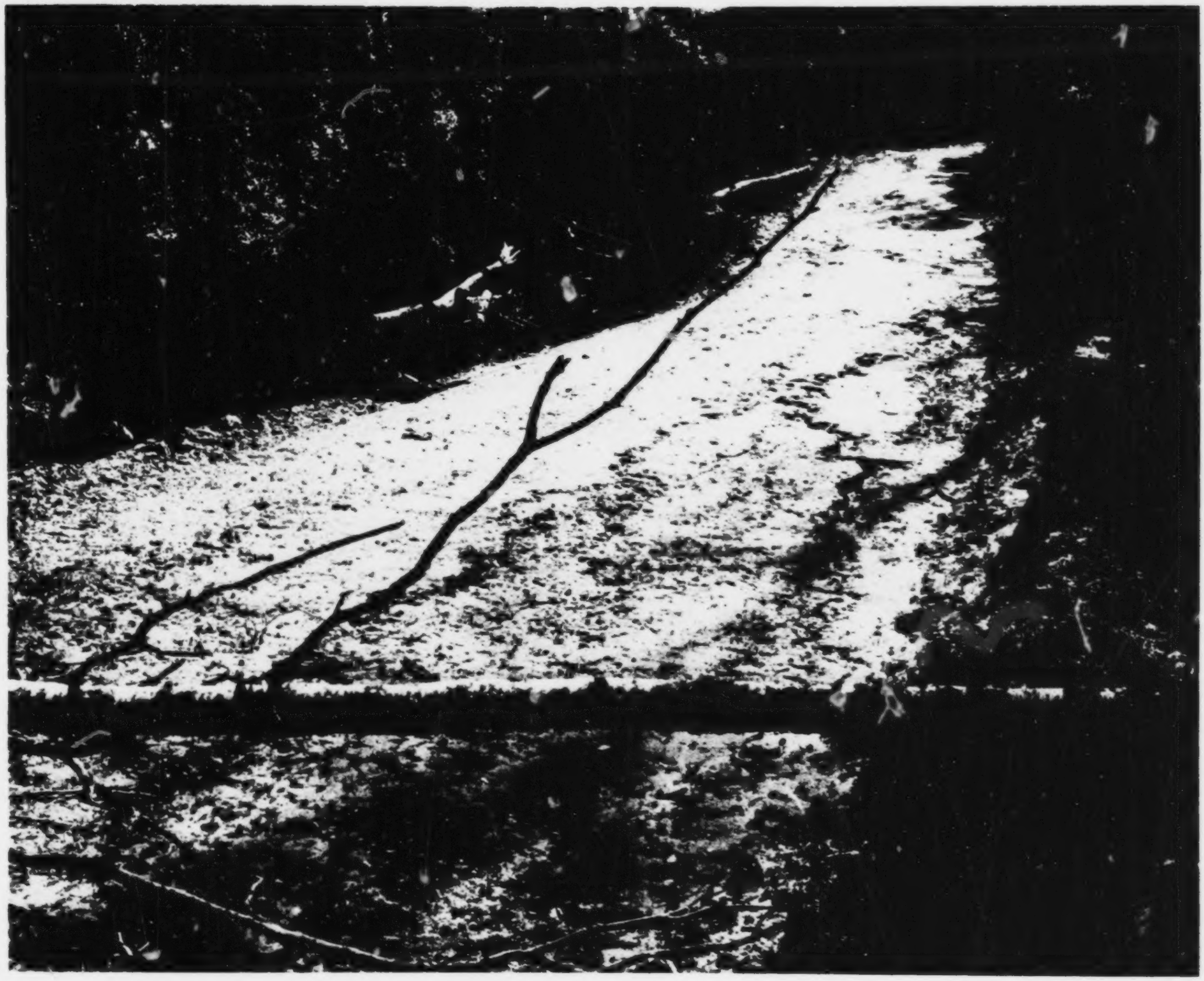

Figure 9. This rilling of an outsloped reach was due to water accumulation from above. The outslope could be of less gradient; more cross drainage would prevent the rilling. Near Fairbanks, Alaska.

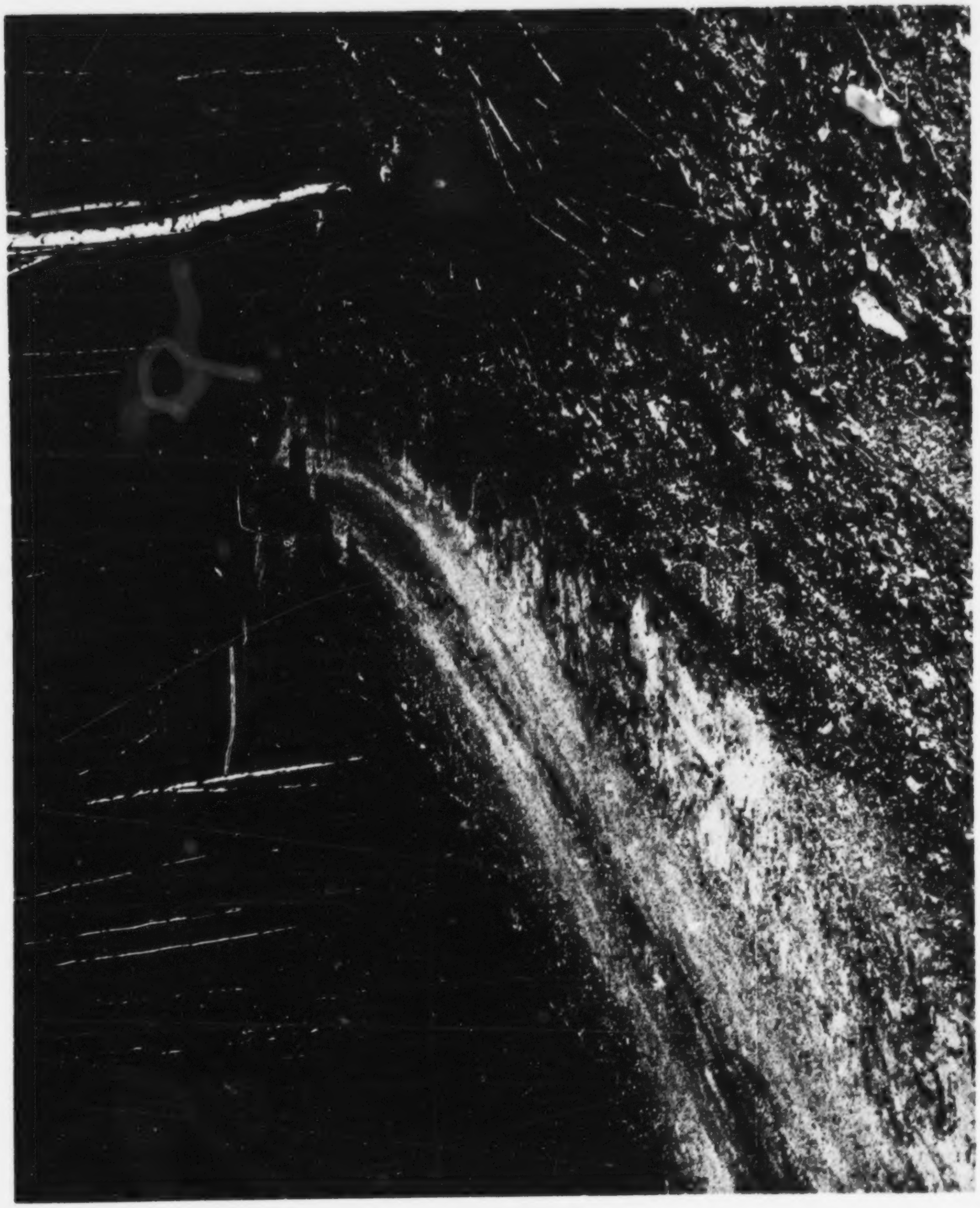

Figure 10. Good cross drainage by outsloping a gravel road surface. Near Fairbanks, Alaska.

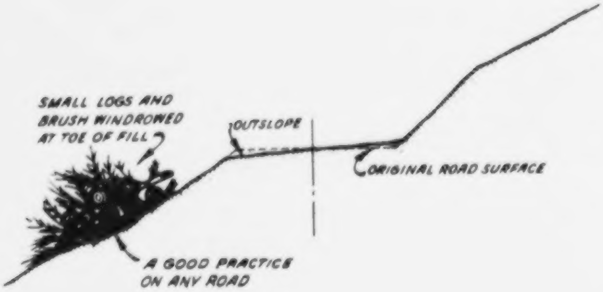
SMALL LOGS AND
BRUSH WINDROWED
AT TOE OF FILL
OUTSLOPE
ORIGINAL ROAD SURFACE
A GOOD PRACTICE
ON ANY ROAD

Figure 11. A cross-sectional design for low gradient logging roads. (From Packer and Christensen, p. 37)

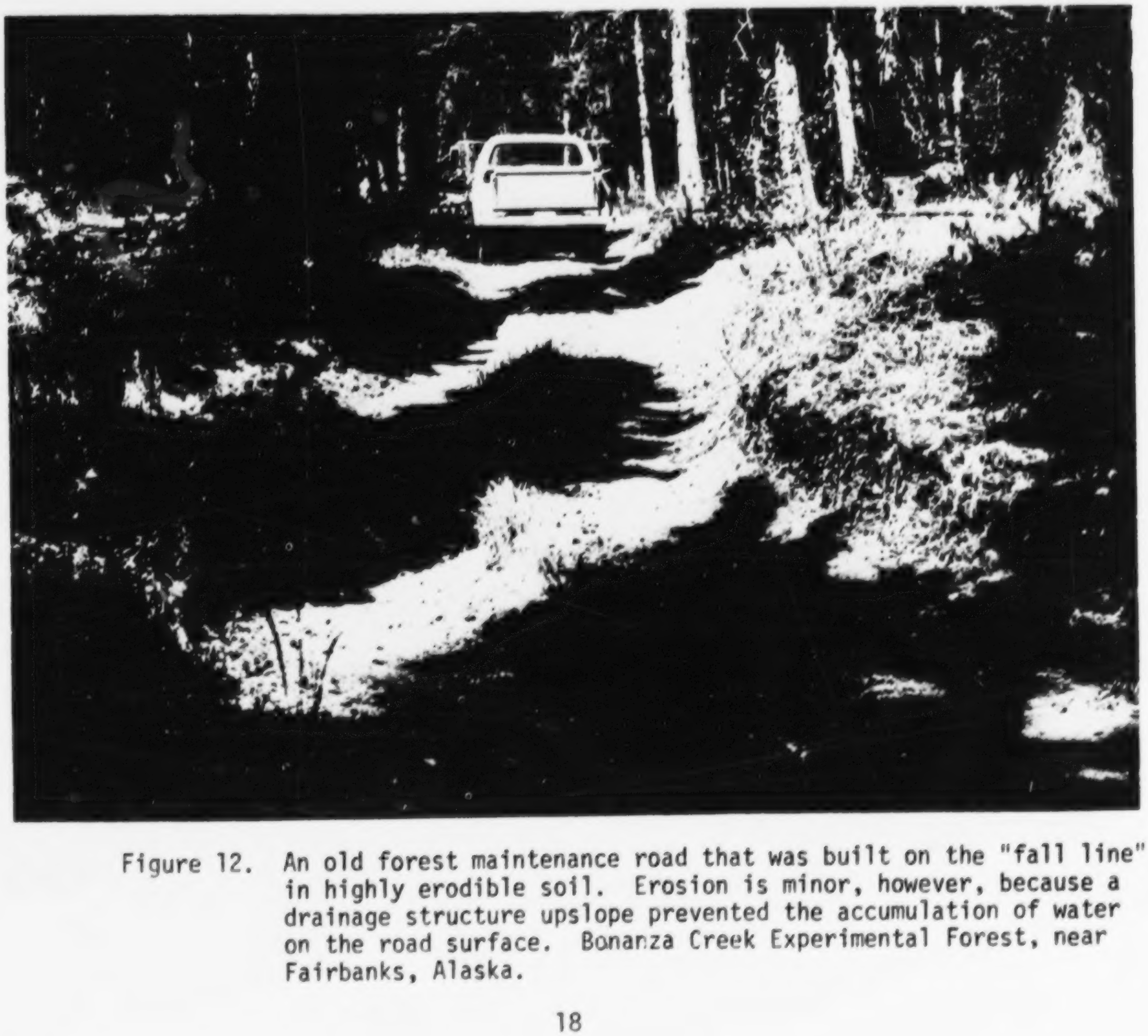

Figure 12. An old forest maintenance road that was built on the "fall line" in highly erodible soil. Erosion is minor, however, because a drainage structure upslope prevented the accumulation of water on the road surface. Bonanza Creek Experimental Forest, near Fairbanks, Alaska.

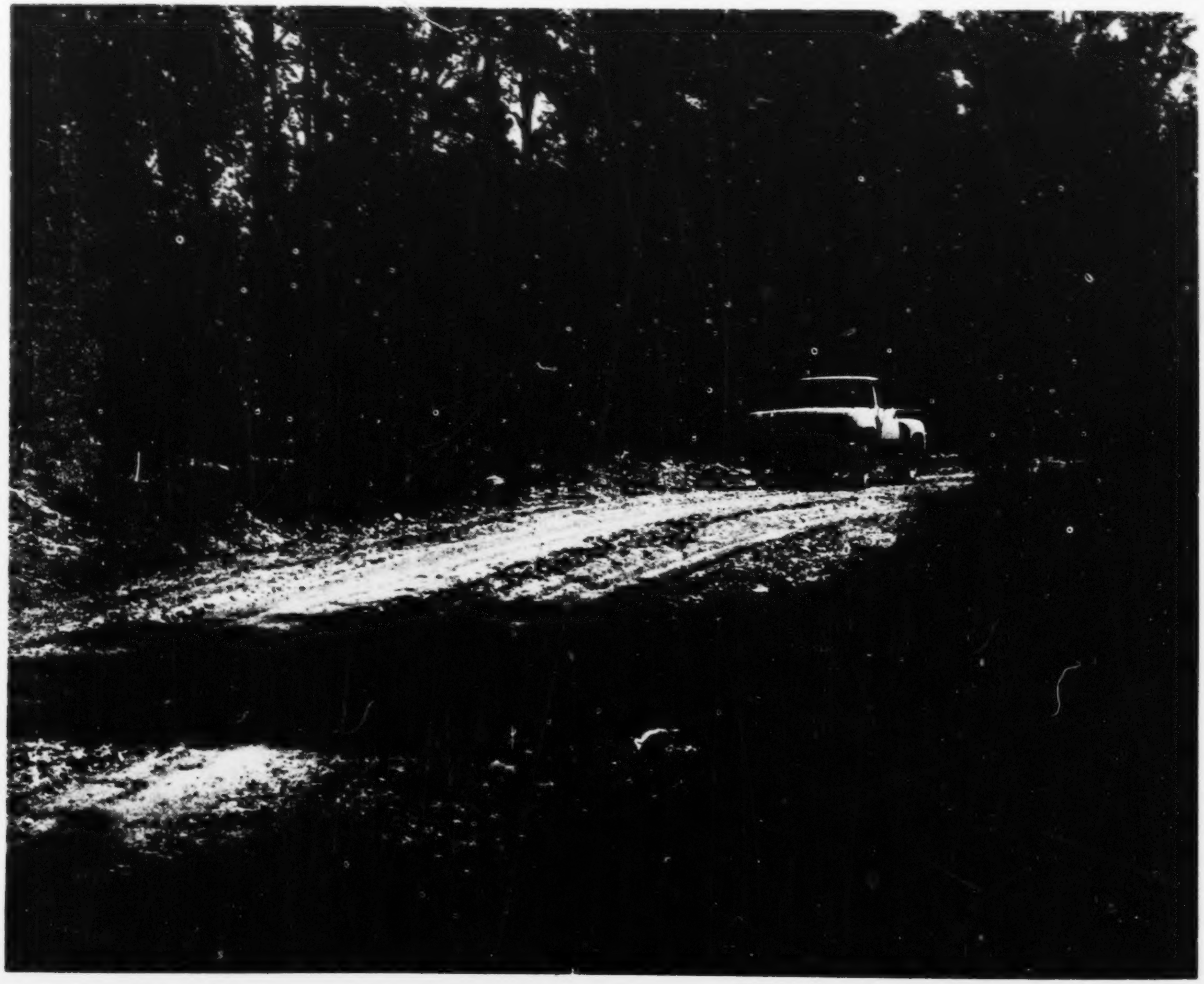

Figure 13. This view of a road drainage shows a diversion accomplished upslope from the road section shown in Figure 12. This diversion leads water into the adjacent forest. On this road such diversions were installed some years after the road was built. This water control has greatly reduced road erosion.

4. Cross streams at right angles and install culverts on the natural gradient of the stream. Adjustments of road alignment may permit crossing a stream at a reach with less gradient.

5. When crossing permafrost areas is unavoidable, design to preserve the permafrost. One acceptable design is to place fill material directly on the undisturbed vegetation layer using endhaul techniques. Vehicular traffic should be kept off permafrost areas except on established roadways.

6. On valley bottoms, crown roads for proper drainage.

7. Road location and design plans should be approved by the appropriate agency before construction commences.

SPUR ROADS

Locate spur roads to take advantage of stable soils and where possible stay on the topographic contour. Design spur roads with the same objectives as those for main haul road. Design roads leading away from landings in such a way as to prevent accumulated water at landings from entering the roads. Design spurs, such as logging skidtrails, to give a systematic network, not a random one. Planning and designing for systematic spurs results in fewer trails with less mileage. Plan the spur roads within the total management plan. Be prepared to take measures to prevent erosion (Figure 14). Design skidtrails to avoid crossing ravines; skid from both sides to reduce erosion. Figures 15 and 16 compare two skidtrails, one of which is eroding.

DRAINAGE

Proper drainage is without doubt the most important single factor to consider in designing and building small access roads; yet it is often neglected, as Figures 17 and 18 clearly show. Design of structures for proper drainage is controlled primarily by topography and the nature and quantity of precipitation; also important are soil properties and forest floor materials.

1. Install culverts on the same gradient as the drainage profile, and, if the stream is perennial and contains fish, select a reach with low gradient. Figure 19 shows an improperly installed culvert that failed. In such situations, a broad gravel ford might be a better crossing method.

2. Use culverts large enough to carry snowmelt runoff; this is frequently the season of maximum drainage. Avoid small-diameter culverts, because they clog easily with debris or ice and are then useless as drainage structures.

3. Protect intakes and outlets of culverts from erosion by riprap or other suitable methods where needed (Figure 20).

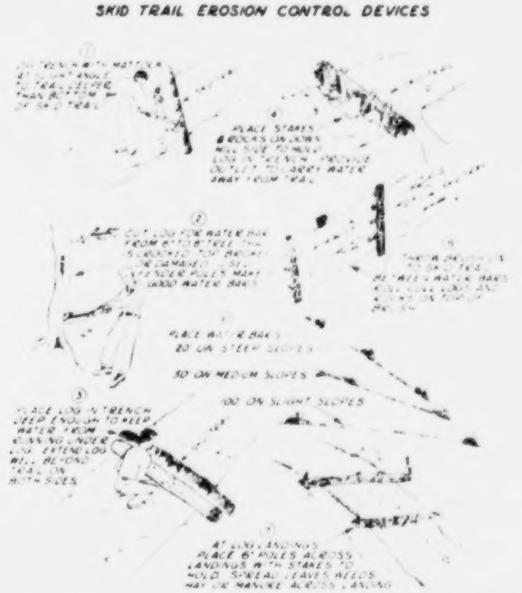
SKID TRAIL EROSION CONTROL DEVICES
1
DIG TRENCH WITH MATTOCK AT SLIGHT ANGLE TO TRAIL DEEPER THAN BOTTOM OF SKID TRAIL
4
PLACE STAKES & ROCKS ON DOWN HILL SIDE TO HOLD LOG IN TRENCH. PROVIDE OUTLET TO CARRY WATER AWAY FROM TRAIL
2
CUT LOG FOR WATER BAR FROM 6" TO 8" TREE THAT IS CROOKED, TOP BROKEN OR DAMAGED [illegible] SLENDER POLES MAKE GOOD WATER BARS
5
THROW BRUSH ON TO SKID TRAIL BETWEEN WATER BARS [illegible]
6
PLACE WATER BARS
20 ON STEEP SLOPES
50 ON MEDIUM SLOPES
100 ON SLIGHT SLOPES
3
PLACE LOG IN TRENCH DEEP ENOUGH TO KEEP WATER FROM RUNNING UNDER LOG. EXTEND LOG WELL BEYOND TRAIL ON BOTH SIDES
7
AT LOG LANDINGS PLACE 6" POLES ACROSS LANDINGS WITH STAKES TO HOLD. SPREAD LEAVES, WEEDS, HAY OR MANURE ACROSS LANDING

Figure 14. This series of diagrams portrays a sequence of operations during the installation of erosion control devices on skid trails. Such devices will not be effective on permafrost areas because thermal erosion is not controlled (another reason for avoiding permafrost where possible). (From Haussman 1960, p. 38)

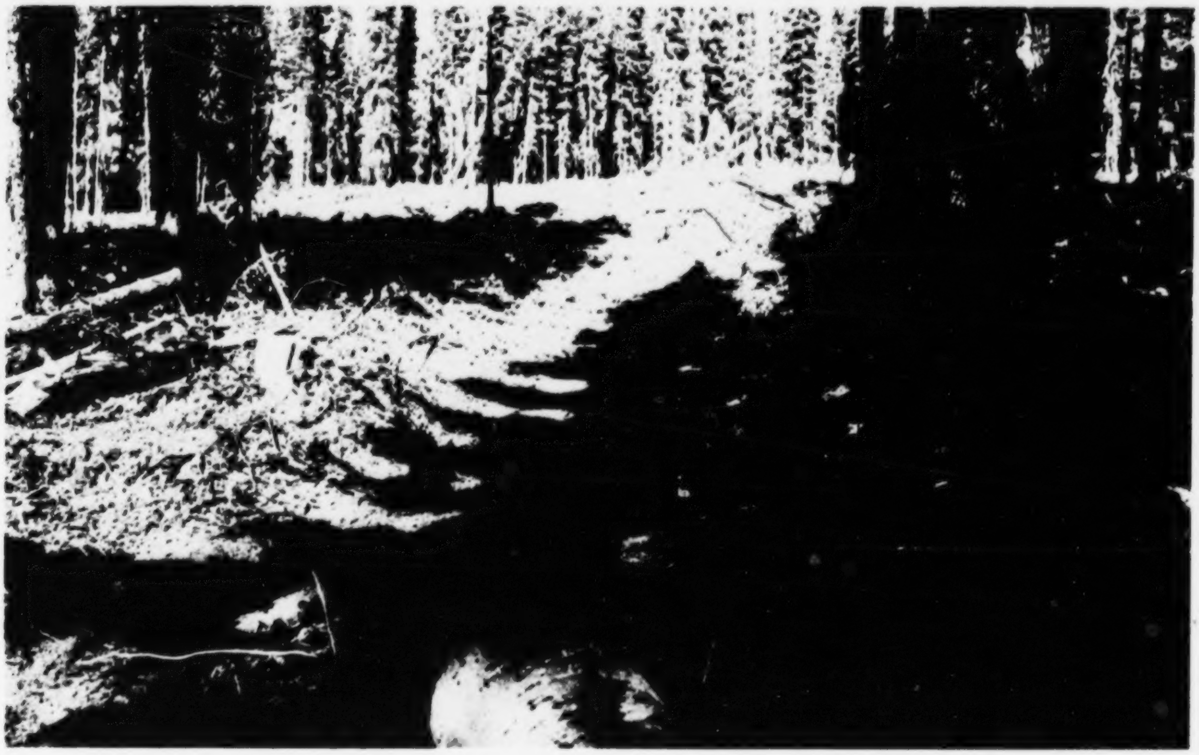

Figure 15. Skid trail over which whole trees were skidded from the clearcut in the background. Skidding unlimbed logs does not appear to disturb the surface of the forest floor as much as does trimmed logs. This skid trail still had a sufficient organic mat that should prevent erosion because no water will be concentrated from upslope to induct erosion.

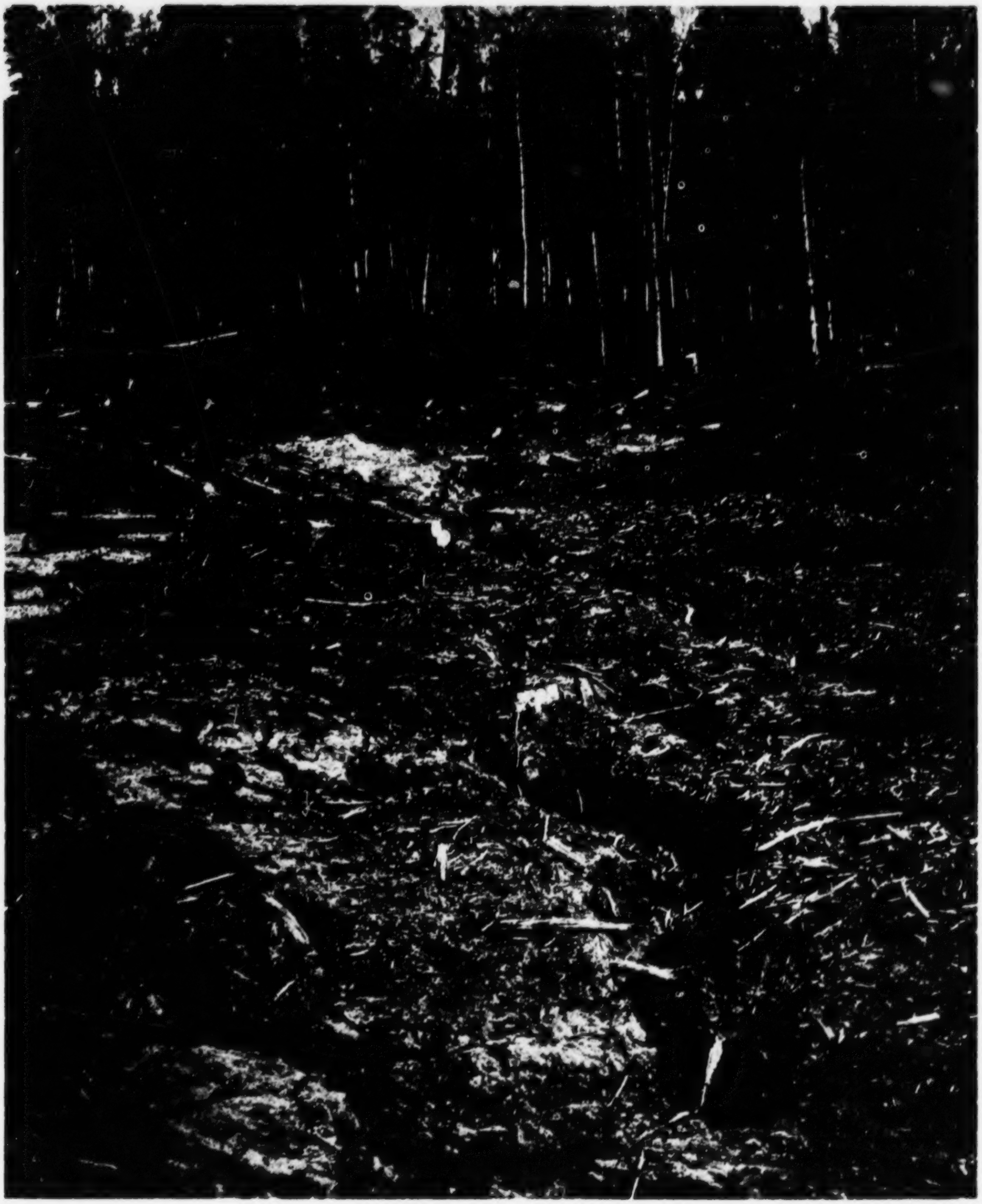

Figure 16. Erosion of a skid trail from an earlier logging operation where silty soil was exposed and no drainage was provided. Erosion here can still be controlled by drainage but may become serious if control is not initiated.

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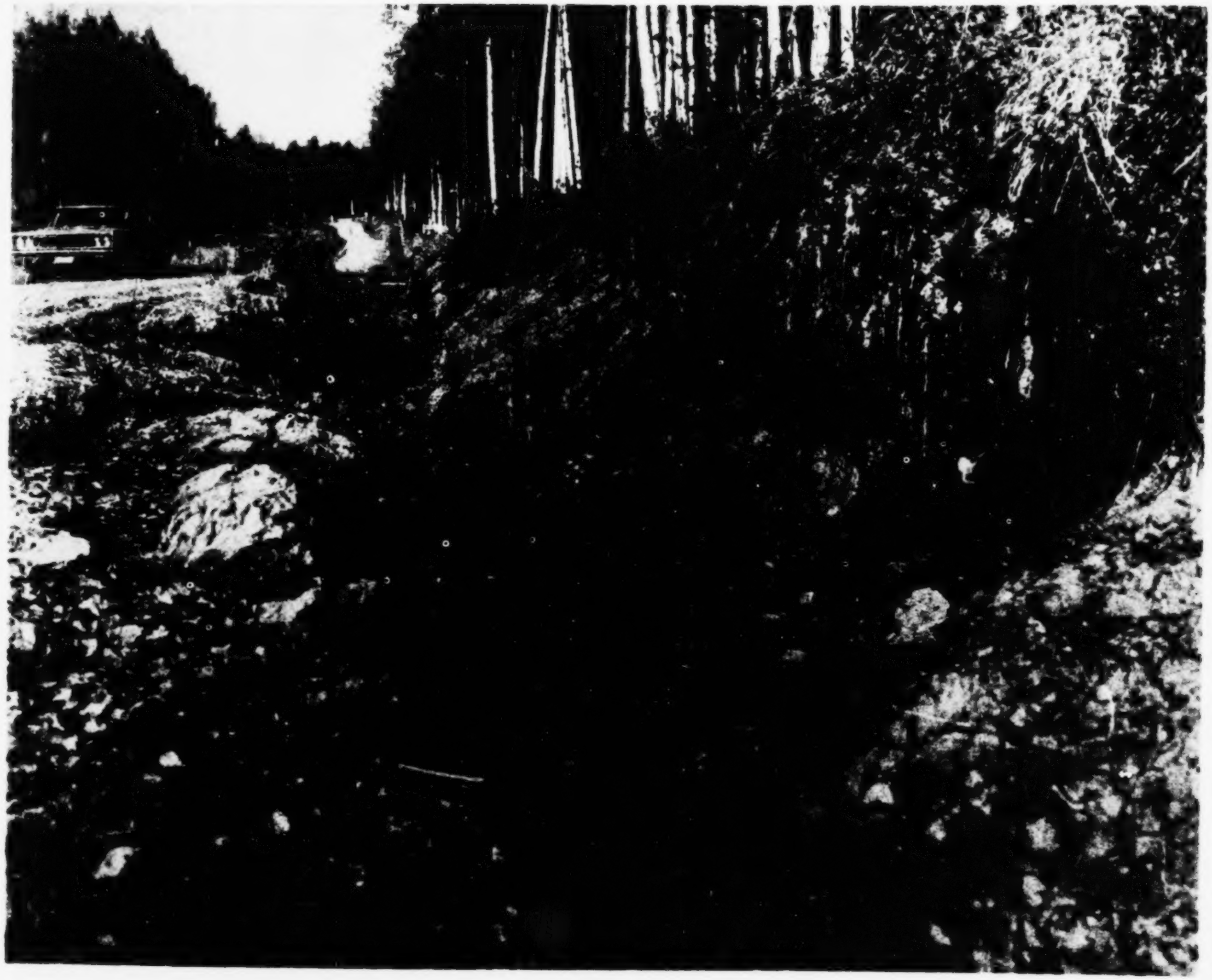


Figure 17. An example of improper design for a residential access road running nearly on the fall line. No drainage structures were put in, with the results shown here. Off Goldstream Road.

Figure 18. Deep gully in a powerline access road, caused by improper drainage. The arrow points to a man standing in a 5- to 6-ft. deep reach.

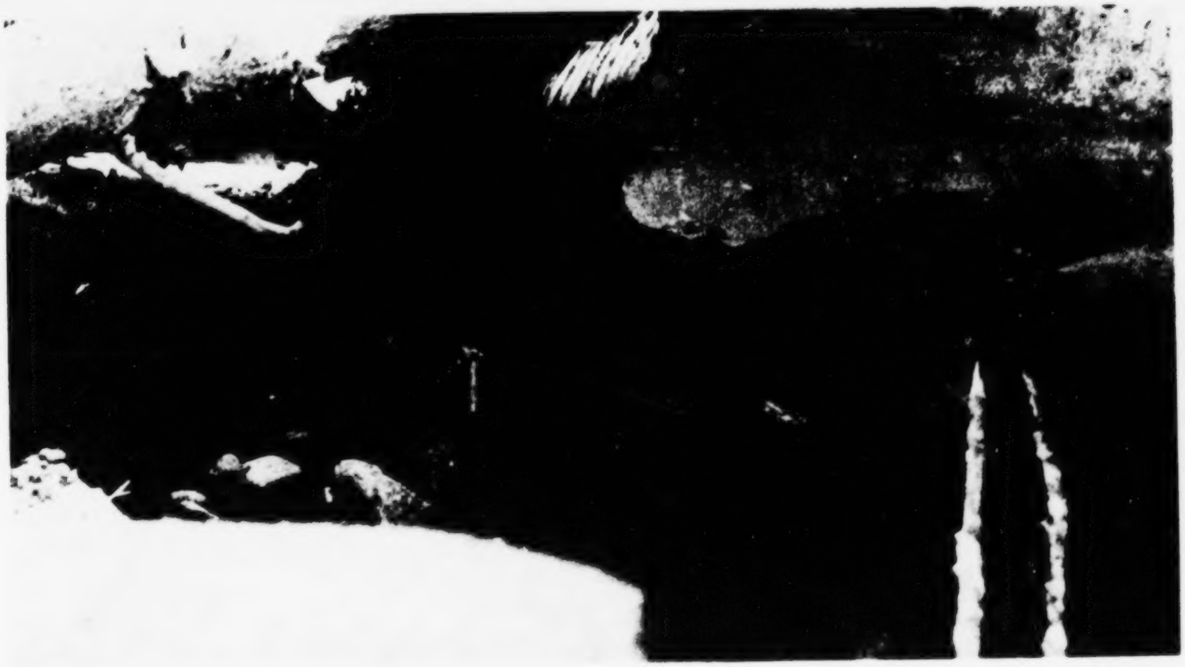


Figure 19. An improperly installed culvert that not only plugged with ice, but was undermined by water accumulated above the fill. This drainage is probably a perennial stream and a bridge or a broad gravel ford appear to be better solutions to this situation.

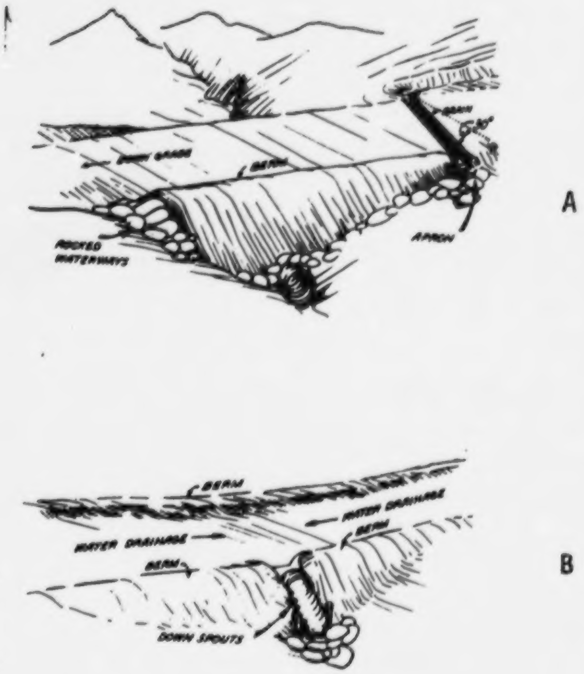


Figure 20, A & B. These diagrams illustrate devices designed to prevent erosion on deep fills. (From Packer and Christensen, p. 40)

4. For streams containing fish, use culvert designs (Figure 21) approved by fishery biologists to permit passage of fish (Metsker 1970, Woodworth 1967).
5. Approach all crossings at right angles if at all possible.
6. Consider bridging as an alternative if proper culvert design results in too high a cost. When bridges are required, consult with the land management agency engineers for recommended structures to fit the conditions, loads, and materials.
7. Use open-top culverts (Figure 22), spaced to prevent accumulations of drainage water, between natural drainages. Protect the area receiving outflow from these culverts by some method to prevent erosion and to spread the water over enough area to allow it to enter the undisturbed forest floor without erosion. Haussman (1960) gives some recommendations for spacing and installing these culverts, although modifications may be required for subarctic conditions.
8. Install culverts near main drainageways to intercept any water that might enter the stream near the main culvert or bridge

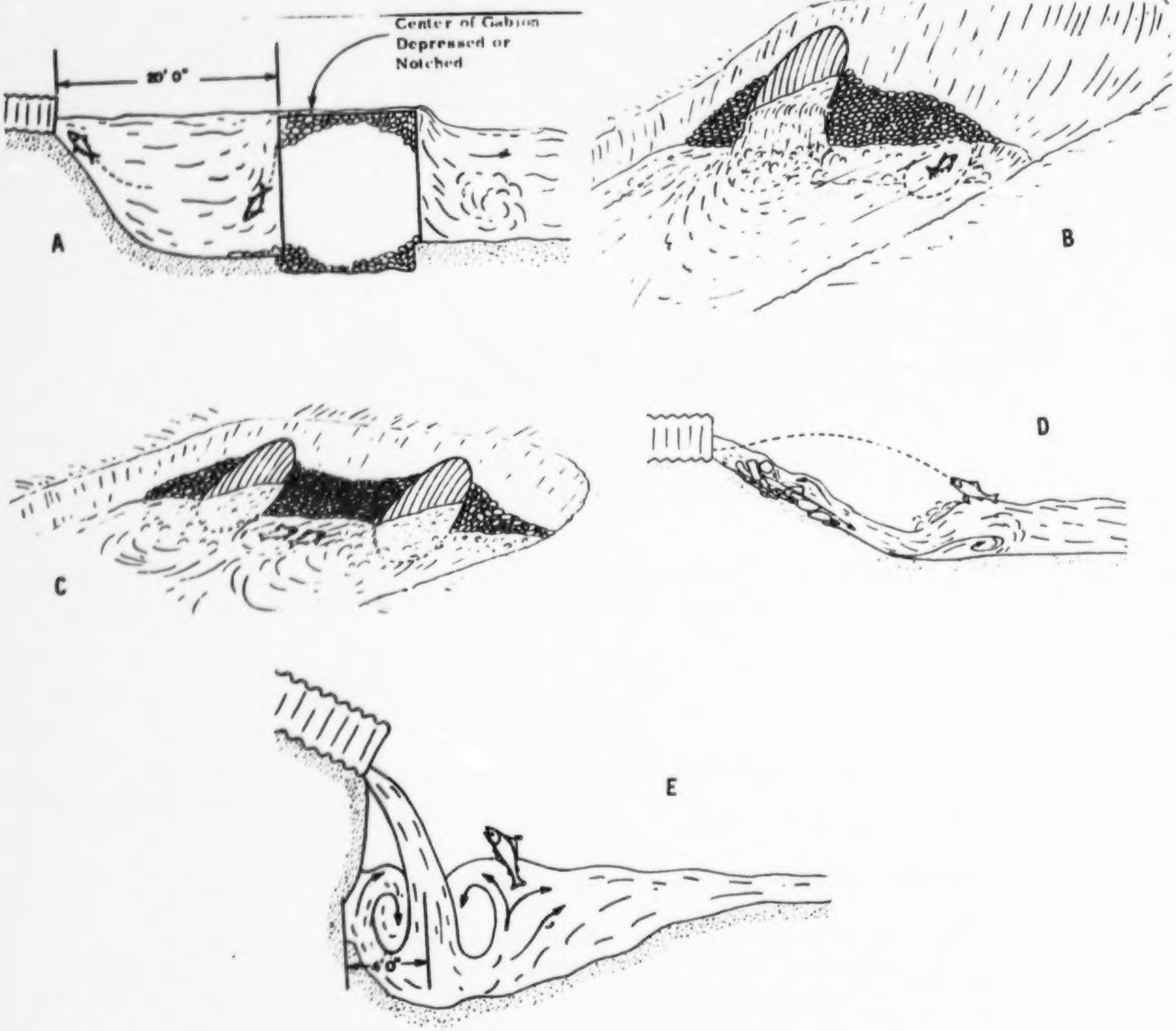


Figure 21, A-E. This series of diagrams shows several methods of culvert installation; some are satisfactory, others act as barriers to migratory fish. (from Metsker 1970, pp. 5-7, 9, 14) A, Protection of downstream channel bottom is often required. Sectional view showing backflood pool and gabion. B, Fish passage may be provided in streams that experience wide ranges of flowing by providing culverts at different elevations. C, Diagrammatic view showing fish in the slack water area. D, Diagrammatic sectional view demonstrating the difficult, or often impossible, jump facing the migrating fish. E, Diagrammatic sectional view of deep plunge pool.

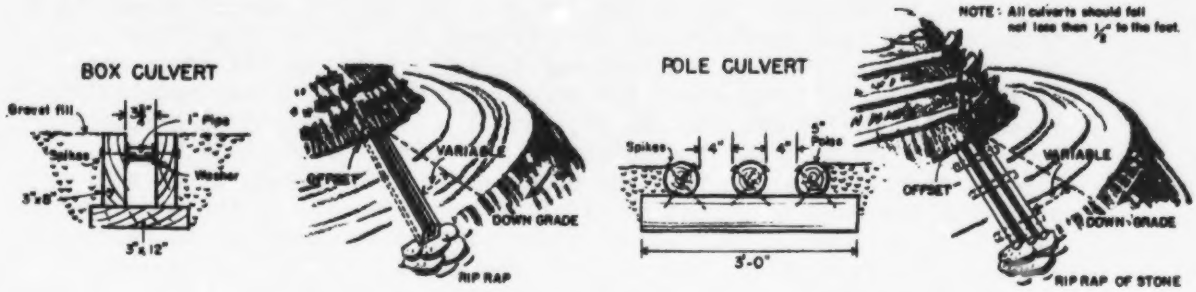

BOX CULVERT
Gravel fill
3½"
1" Pipe
Spikes
Washer
3"x8"
3"x12"
OFFSET
VARIABLE
DOWN GRADE
RIP RAP
POLE CULVERT
Spikes
4"
4"
5" Poles
3'-0"
NOTE: All culverts should fall not less than ½" to the foot.
OFFSET
VARIABLE
DOWN GRADE
RIP RAP OF STONE

Figure 22. These diagrams show two open-top culvert designs with suggested dimensions and recommended procedures for installations. (From Haussman 1960, p. 7 and 9)

(Figure 17A); divert this water from the stream bank or protect the outlet.

EROSION CONTROL

Proper location and design of roads will reduce erosion, but some portions of the system may require special measures. Figure 23 diagrams two ways to prevent road erosion without installing culverts.

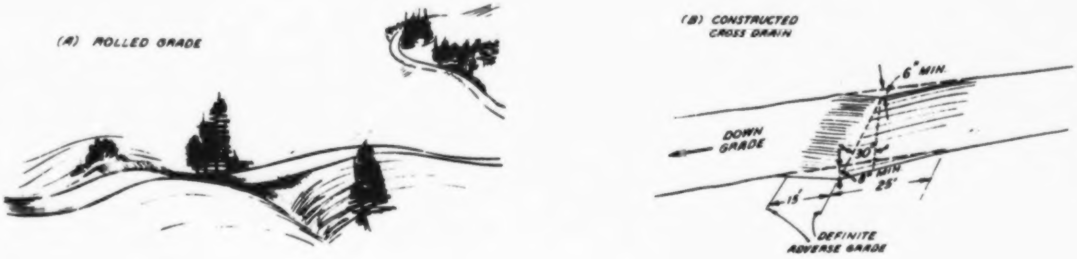
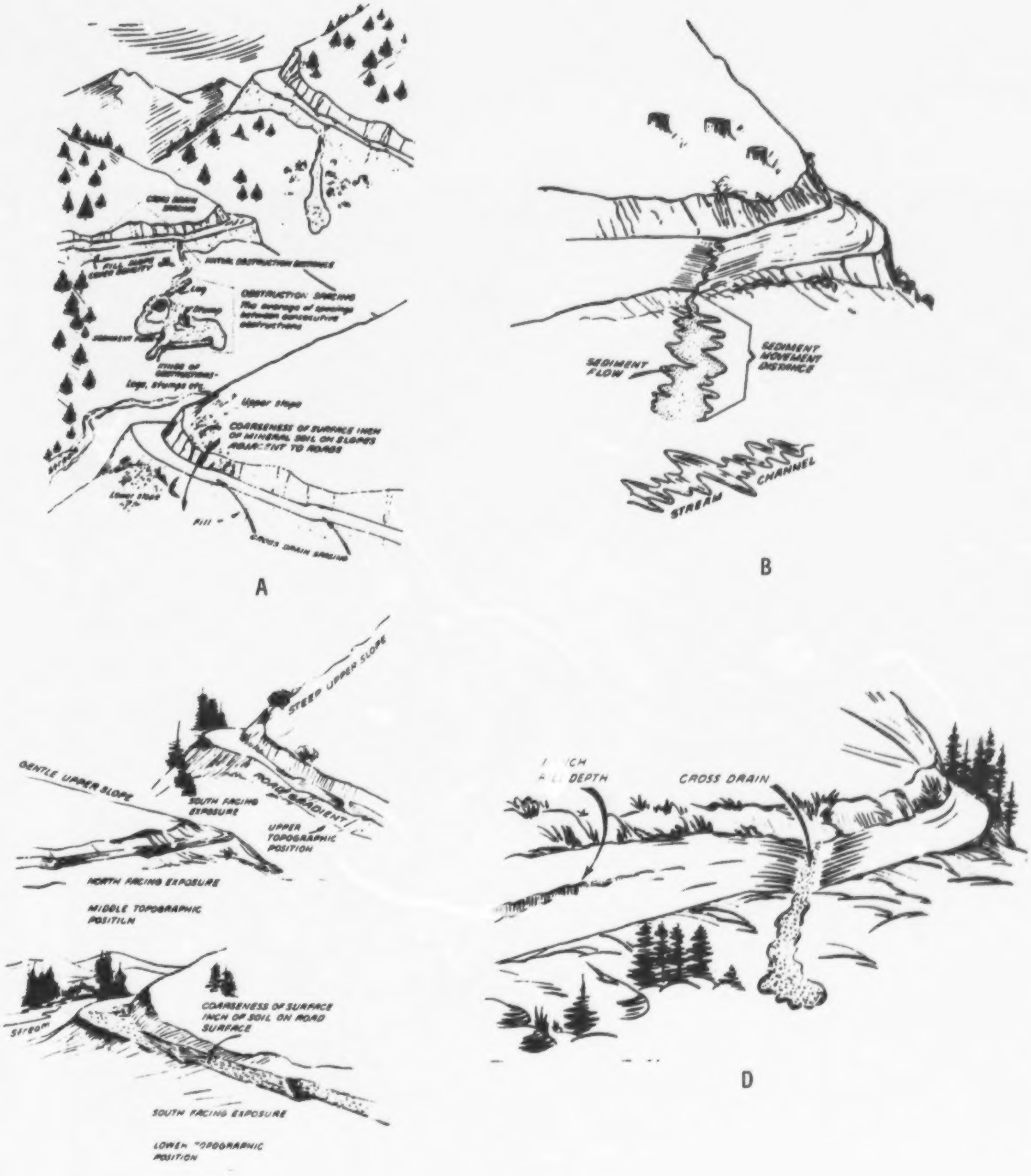

(A) ROLLED GRADE
(B) CONSTRUCTED CROSS DRAIN
6" MIN.
DOWN GRADE
30°
8" MIN
25°
15°
DEFINITE ADVERSE GRADE

Figure 23. Two construction techniques that effectively prevent accumulation of runoff without the need for additional materials such as culverts or bridges. A, rolled grade, and B, constructed cross drain. (Packer and Christensen, p. 34)

Figure 24 illustrates some of the factors that control spread of sediment or erosion of road surfaces and some methods for controlling these factors. Slash from the right-of-way clearing piled on the lower edge of fresh fills will intercept and spread sediments until new vegetation is established (Figures 25, 26, 27, and 28). Three effective attempts and one failure to prevent erosion are shown in Figures 25-28. In logging operations where skidding down slopes is required, structures should be designed to divert runoff from the skidtrail to the undisturbed forest litter layer. Kidd (1963) gives some recommendations to reduce erosion from skidtrails. Use logging debris to control erosion along abandoned skidtrails as the logging operation proceeds.

Protect areas below open-top culverts from erosion by placing rock basins or logging debris to dissipate the energy of the falling runoff water (Figures 20 and 22).

When flowing streams are to be bridged in winter with ice bridges, avoid high banks that would require deep cutting for the approach (Figure 29).


INITIAL OBSTRUCTION DISTANCE
Log
Stump
OBSTRUCTION SPACING
The average of spacings between consecutive obstructions
Types of obstructions-
Logs, stumps etc.
Upper slope
COARSENESS OF SURFACE INCH OF MINERAL SOIL ON SLOPES ADJACENT TO ROADS
Lower slope
Fill
CROSS DRAIN SPACING
SEDIMENT FLOW
SEDIMENT MOVEMENT DISTANCE
STREAM CHANNEL
STEEP UPPER SLOPE
GENTLE UPPER SLOPE
ROAD GRADIENT
SOUTH FACING EXPOSURE
UPPER TOPOGRAPHIC POSITION
NORTH FACING EXPOSURE
MIDDLE TOPOGRAPHIC POSITION
Stream
COARSENESS OF SURFACE INCH OF SOIL ON ROAD SURFACE
SOUTH FACING EXPOSURE
LOWER TOPOGRAPHIC POSITION
CROSS DRAIN

A

B

C

D

Figure 24. These diagrams illustrate some factors that control the spread of sediment and erosion of road surfaces and some measures that may retard sedimentation of nearby streams: A. Factors that affect distance sediment moves downslope; B. Sediment movement downslope from a road cross drain; C. Factors affecting erosion of road surface; D. Rill erosion on a road surface below a cross drain. (From Packer and Christensen, pp. 8, 3, 6, and 2, respectively)

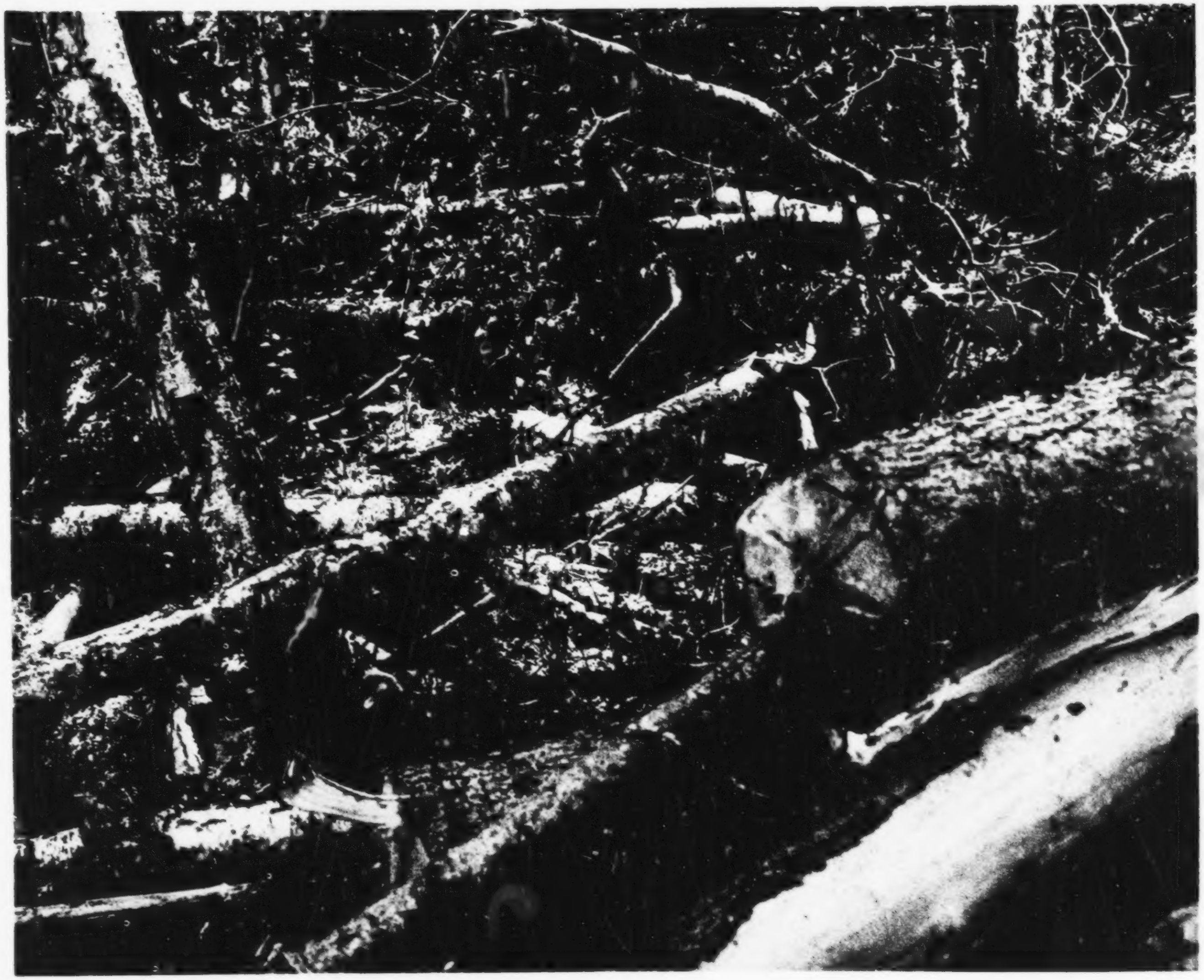


Figure 25. A good example of debris on the toe of a fill slope that acts as a sediment trap.

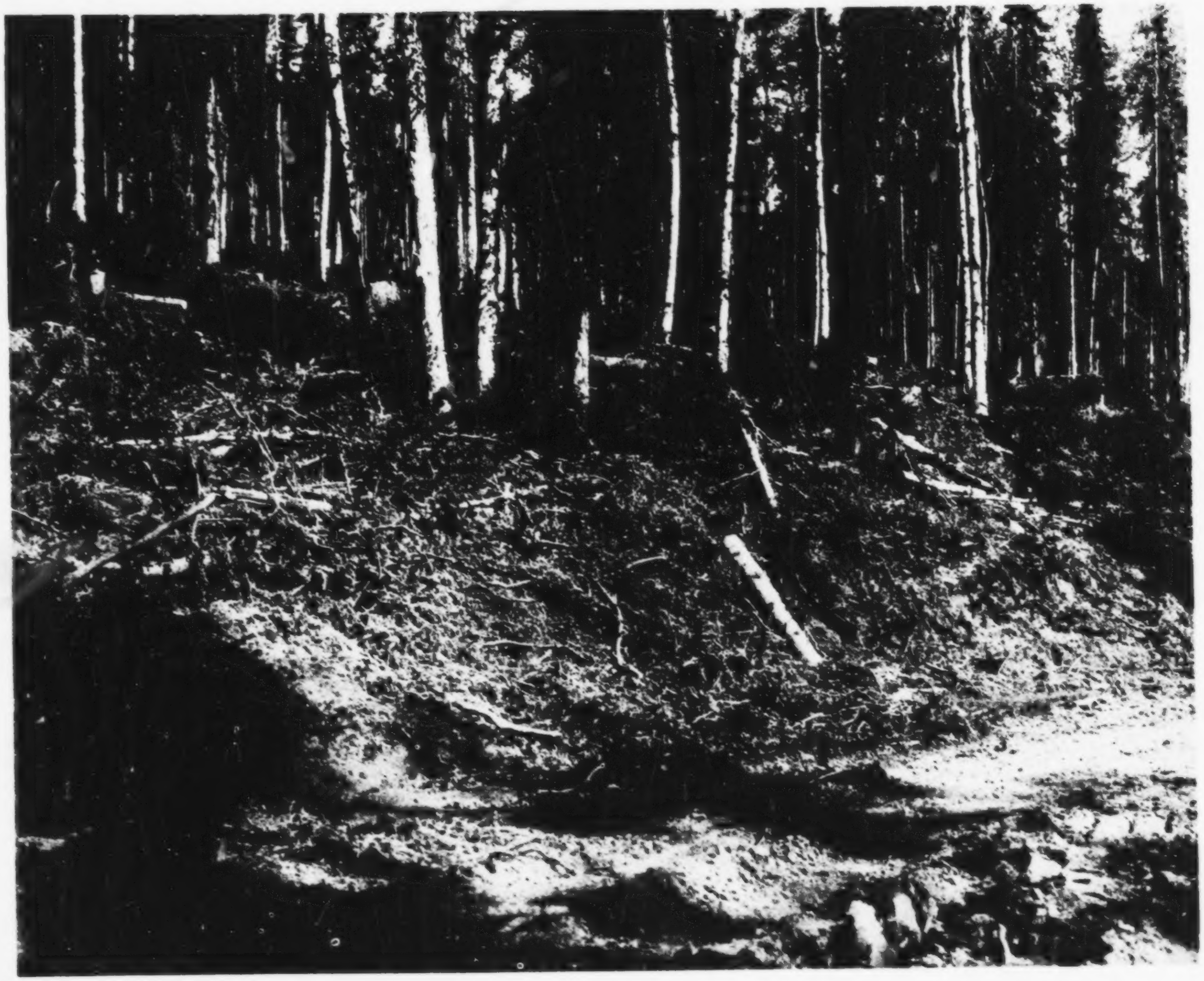


Figure 26. Logging debris can effectively protect cut slopes if the cut is not too deep.

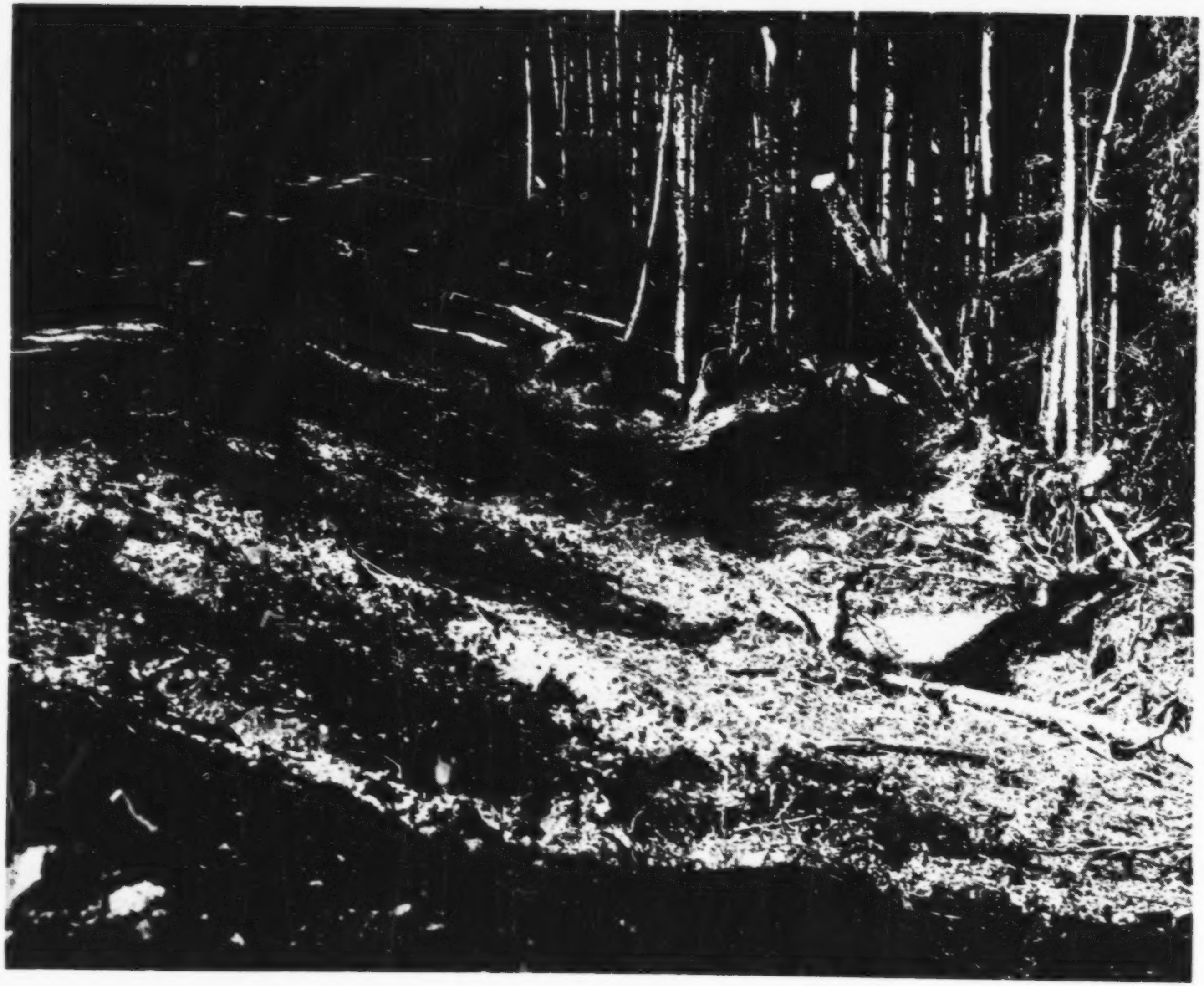


Figure 27. An example where debris from road clearing was not utilized as erosion control material. In this instance, no forethought was given to erosion control of fill slopes during road construction, and debris was moved too far downslope to be of value in erosion control.

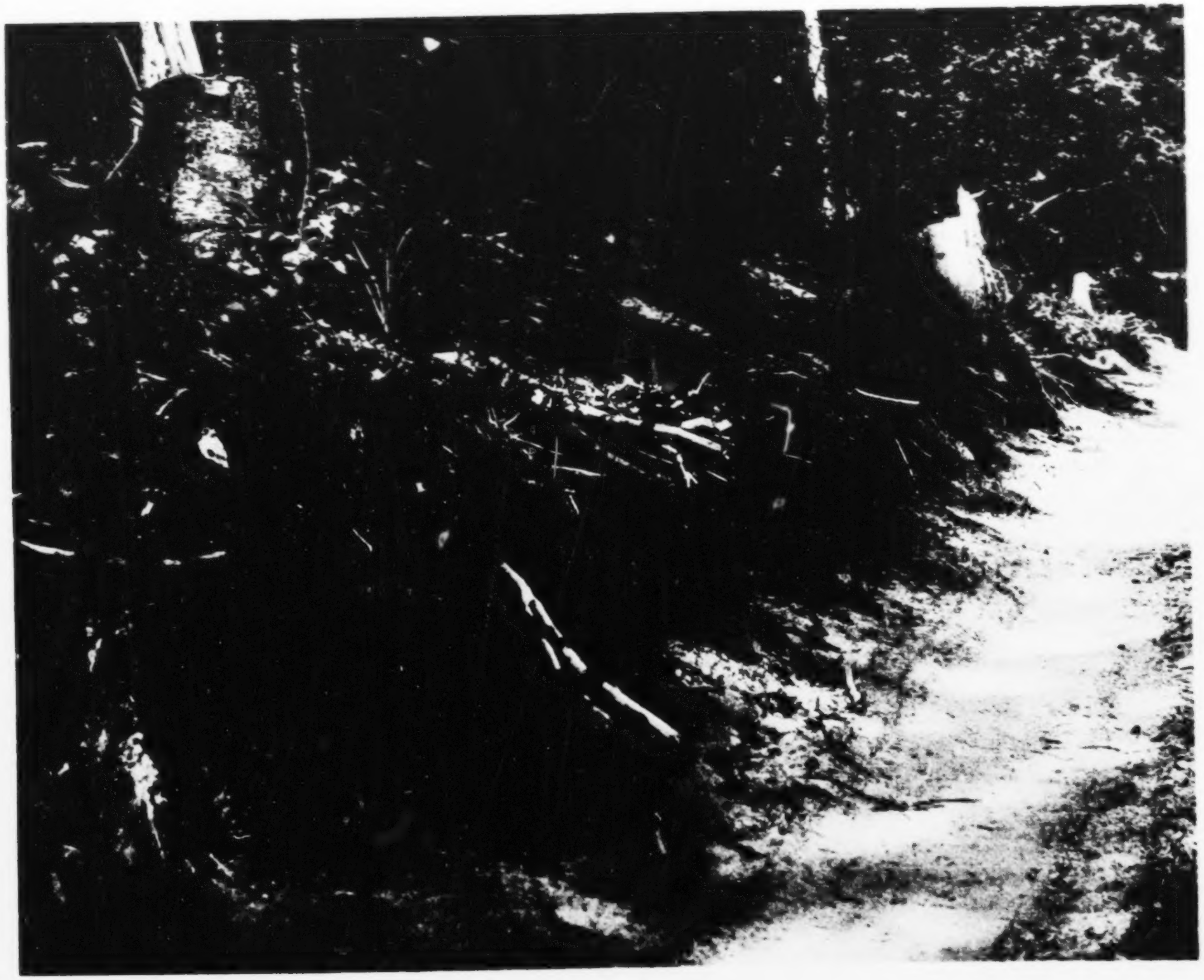


Figure 28. The forest floor vegetation mat is an effective erosion control agent for cuts if not disturbed. Stumps on the edge of the cuts are an important part of this mat and should be left in place unless they actively interfere with the hauling operation.

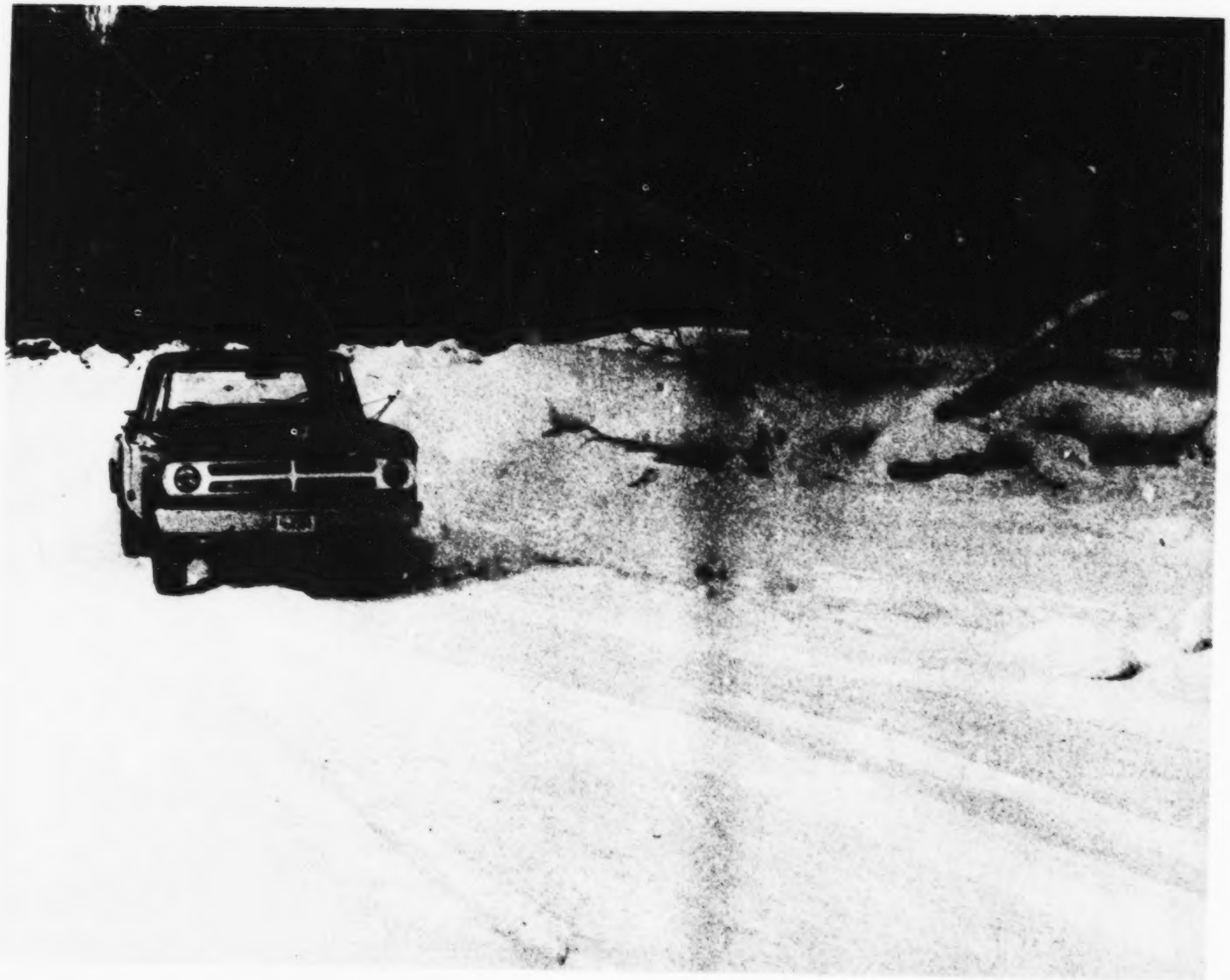


Figure 29. An ice bridge across the Chena River with a proper approach made without extensive bank cutting. The water under the pickup was about 8 feet deep during the summer.

CONSTRUCTION

It is during the actual construction process that most environmental damage is likely to occur. All the proper safeguards designed into the plan are useless unless the operator follows a good operation procedure. Contracts should include provisions for temporary sediment control while construction is under way. Costs for this control are to be included in the total estimate, just as other construction costs. When interim measures to prevent erosion during the construction period are neglected, considerable sedimentation can result.

High quality road construction should be insisted upon by the land owner or his representative. Regular inspections should be made during construction by a qualified official with authority to assure that road construction meets design requirements.

Before construction starts, preferably after the planning document has been approved, conferences between the equipment operators and the resource manager should be held. If the operators are made aware of the need for environmental protection, and are actively participating in it, detailed inspections may not be so necessary. Unless the operator, his crew, and the resource manager enter into the spirit of environmental protection, no amount of inspection can prevent damage. The ultimate objective is to motivate each person concerned so that his efforts to protect the environment will result in a better place to live.

SURVEYING AND RIGHT-OF-WAY CLEARING

1. Before and during construction activities, the operator should be briefed on particular environmental problem areas by appropriate specialists. These briefings should include fire prevention and suppression training for all personnel.

2. During establishment of centerline, grades, and boundaries, equipment should be kept on the right-of-way whenever possible. Utilization of equipment off established routes leads to erosion and uncontrolled permafrost melting.

3. All timber should be cut close to the ground to preclude unsightly stumps remaining after completion of the project. Timber should be felled into the right-of-way and away from water courses. Standing timber should not be cleared by bulldozing. The results of such a practice are unsightly and can be a fire and insect hazard (compare Figures 30 and 31). Clearing width should be kept to the minimum required for the right-of-way in order to maintain esthetic values. Contrasting clearing widths are compared in Figures 32 and 33. Figure 32 shows an ample width.

4. The organic mat should be preserved where the design calls for overlay. This procedure is the most effective method to control permafrost melting.

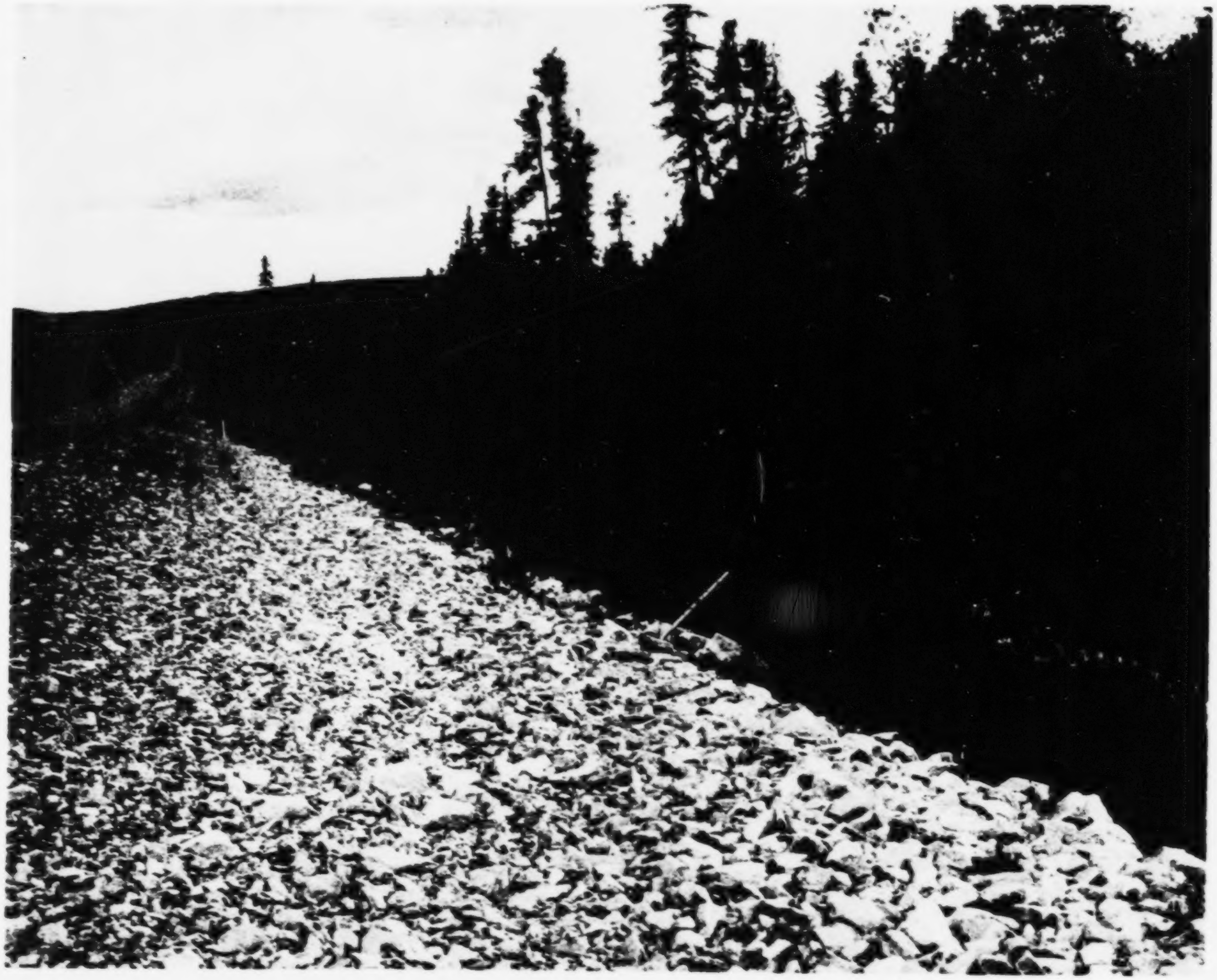


Figure 30. Proper right-of-way clearing. Slash disposal was probably by burning; it could also be handled by chipping. If the subgrade is muskeg, permafrost, or poorly drained, the slash could be hand placed as a mat under the fill.

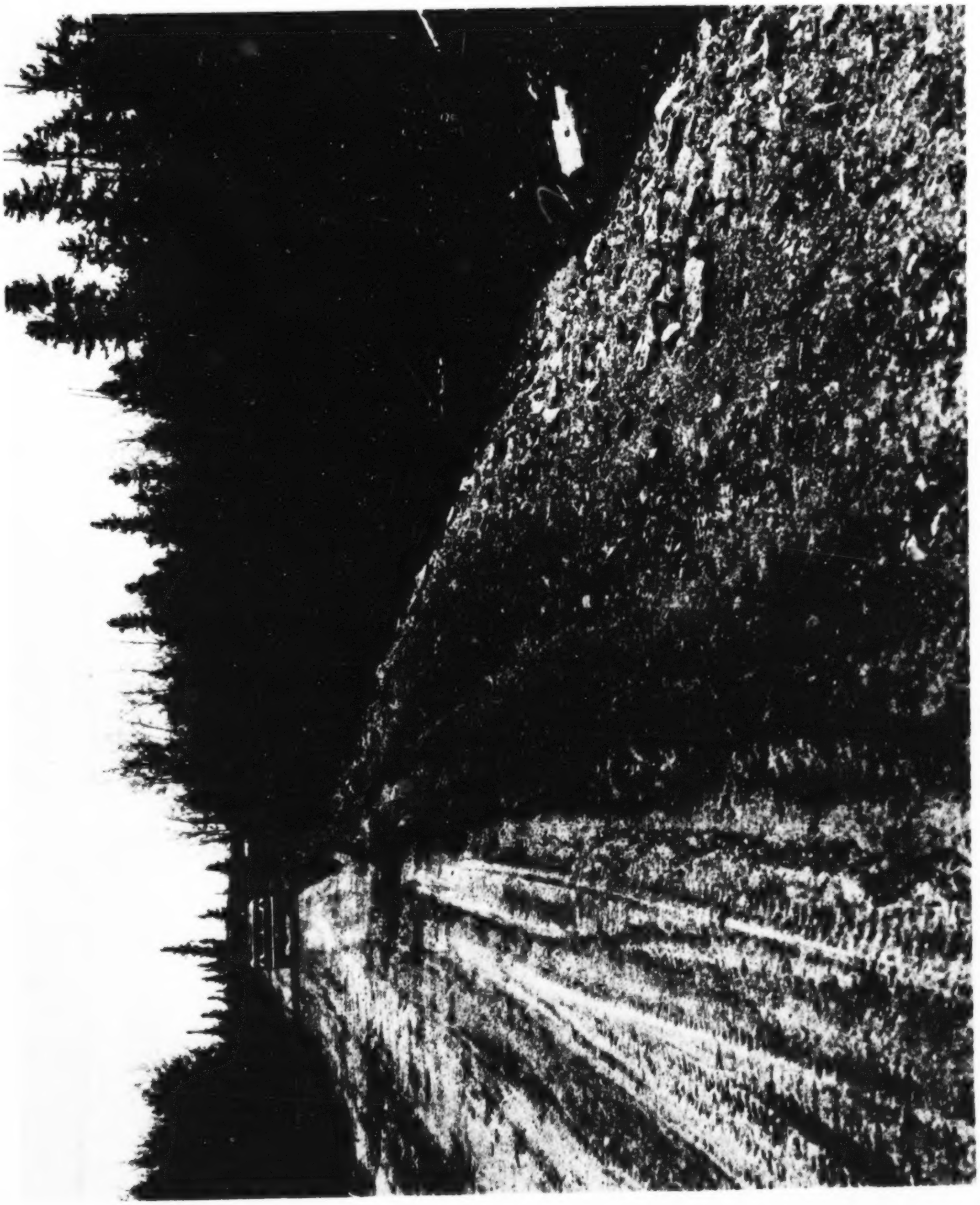


Figure 31. Clearing by bulldozer leaves berm piles such as these. New Minto Road, 1973.

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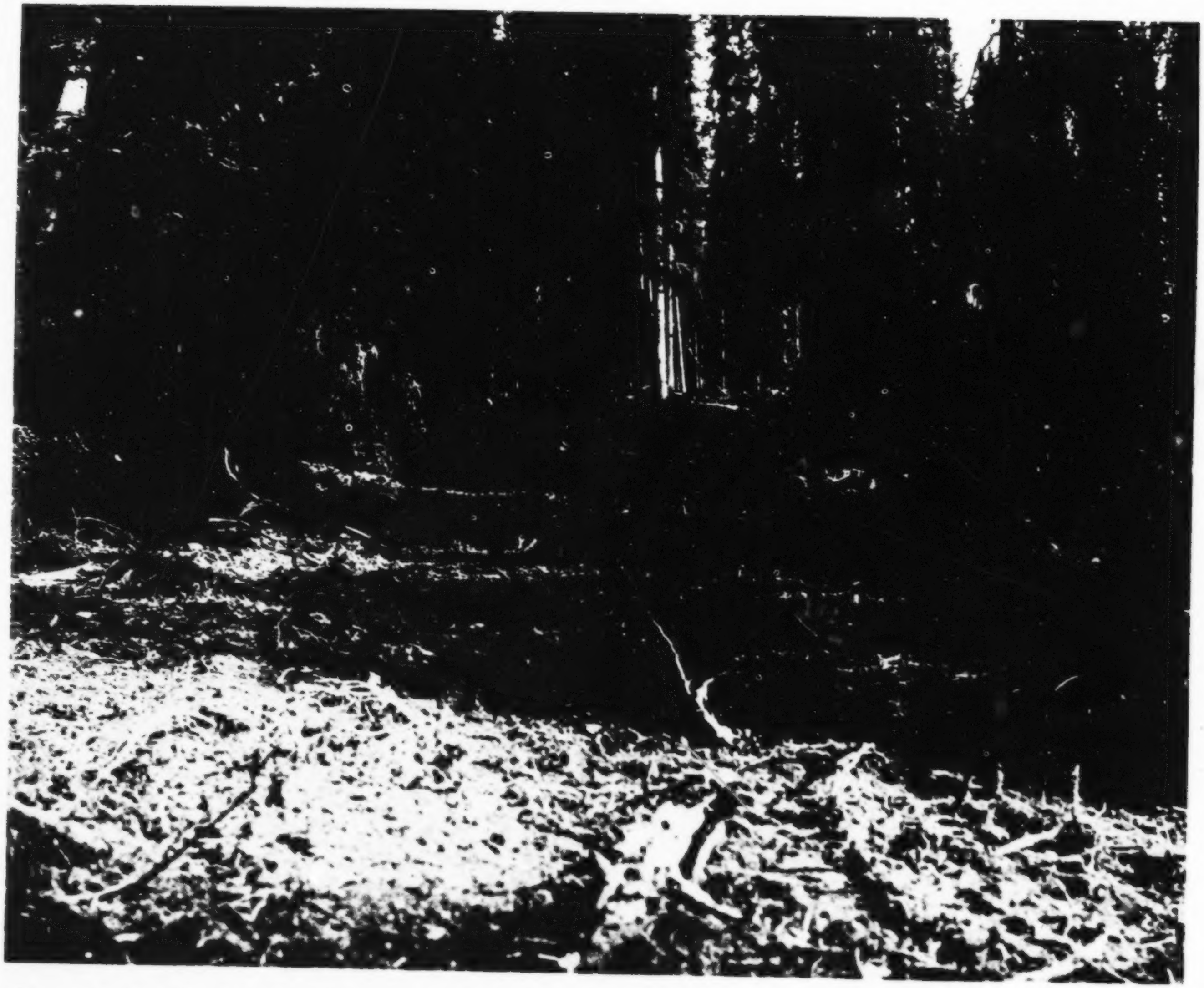

Figure 32. Completed clearing for a forest haul road before hauling had commenced. Although this clearing removed a minimum number of trees, it is amply wide to accomodate trucks hauling 80-ft. logs. Such a road is recommended to prevent erosion, as a minimum amount of the forest is disturbed.

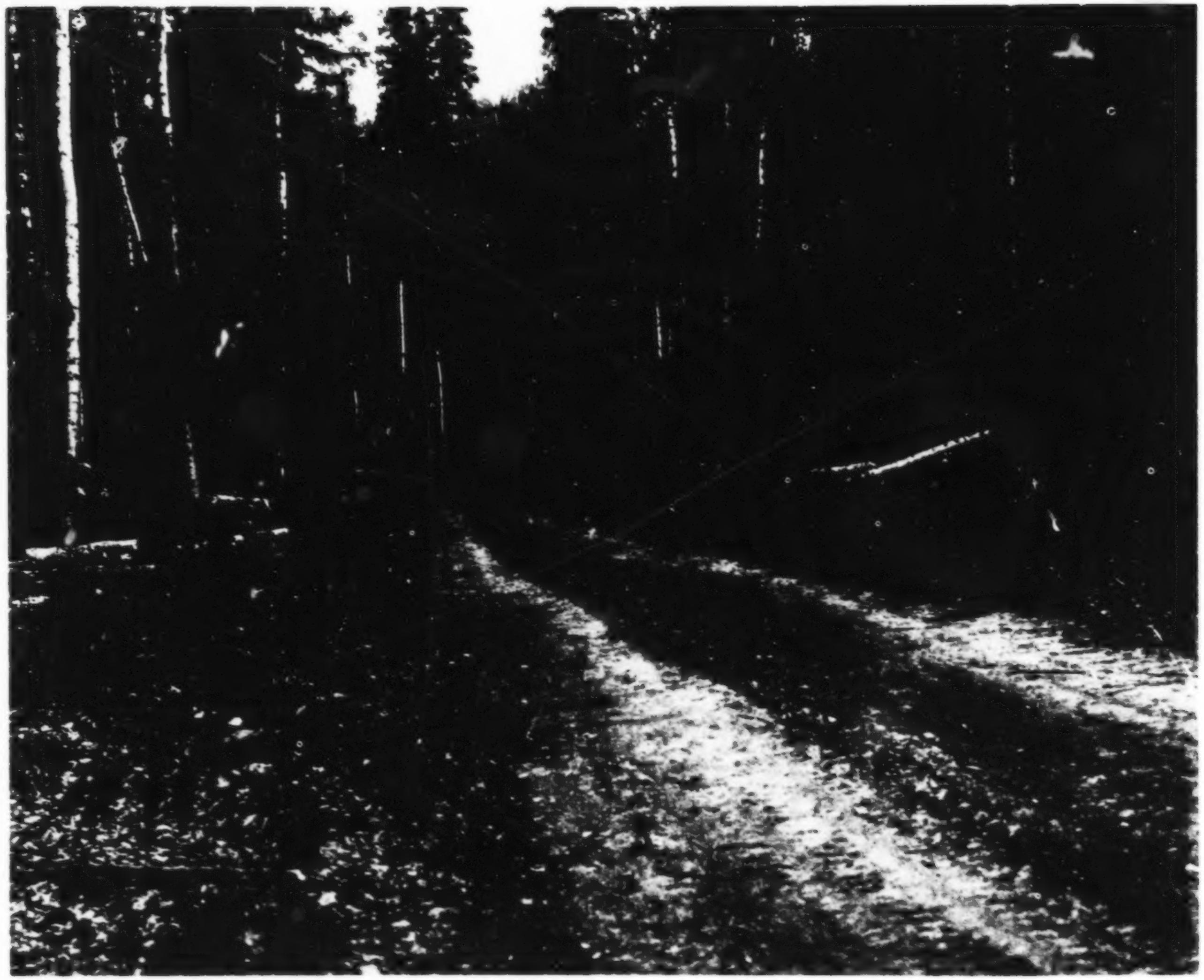

Figure 33. Another portion of the haul road shown in Figure 32 that was built the previous summer. This view illustrates excessive clearing for a haul road to achieve the limited objective of log hauling; this cleared zone is about twice as wide as necessary for such a road, but is satisfactory otherwise.

5. Logs should not be skidded or yarded across any stream without prior approval and log landings should not be located on the banks of any live stream. Where use of heavy equipment would be detrimental to existing conditions, hand clearing operations should be used (Burns 1972).

6. All debris from clearing operations should be disposed of by windrowing at the toe of the fill to act as sediment traps (Figures 11 and 25).

EARTHWORK

1. Where the road design calls for full bench construction, the full cut is made, excess excavation is end-hauled from the cut, and it is deposited in stable locations well above high-water levels. Waste materials should not be deposited directly into stream channels. Where necessary, all fill should be compacted to reduce the entry of water and to prevent the fill material from settling.

2. Construction-area drainage should be collected and kept out of streams. Seepage pits or other confinement measures can be used to prevent diesel oil, fuel oil, or other liquids from running into streams. Use drip collectors on oil-transporting vehicles.

3. Soil disturbances can be kept to a minimum by constructing roads only when soil moisture conditions are favorable. New roads should be rough graded only as far as can be completely finished during the current season. Ditches and drainage installations should be finished on the section being worked on before another section is opened up or before shutting down for the season. Figure 34 shows a new logging road that was stable during the fall and winter, but eroded during breakup before construction was completed. Figure 27 shows similar results on bar ditches running straight down the slope on a small residential development near Fairbanks.

4. Each graded section should be fully backsloped, except where vertical cut banks are more stable than sloping ones. In critical slump areas, large cuts should be graded to slopes of not more than 2 to 1 and horizontal drain pipes used. Also, all large fill areas should be protected with surface drainage diversion systems. Culverts should be placed to cause the minimum possible channel disturbance and fill materials kept away from culvert inlets and outlets. During road construction, earth moving activities should not be permitted when the soils are saturated. Road machines are allowed to work in streambeds only for laying culverts or constructing bridge abutments, and then only in the absence of spawning fish. Streamflow should be diverted from the construction site whenever possible to prevent or reduce turbidity.

5. Drainageways should be clear of all woody debris generated during road clearing or construction. Clearing debris should be windrowed

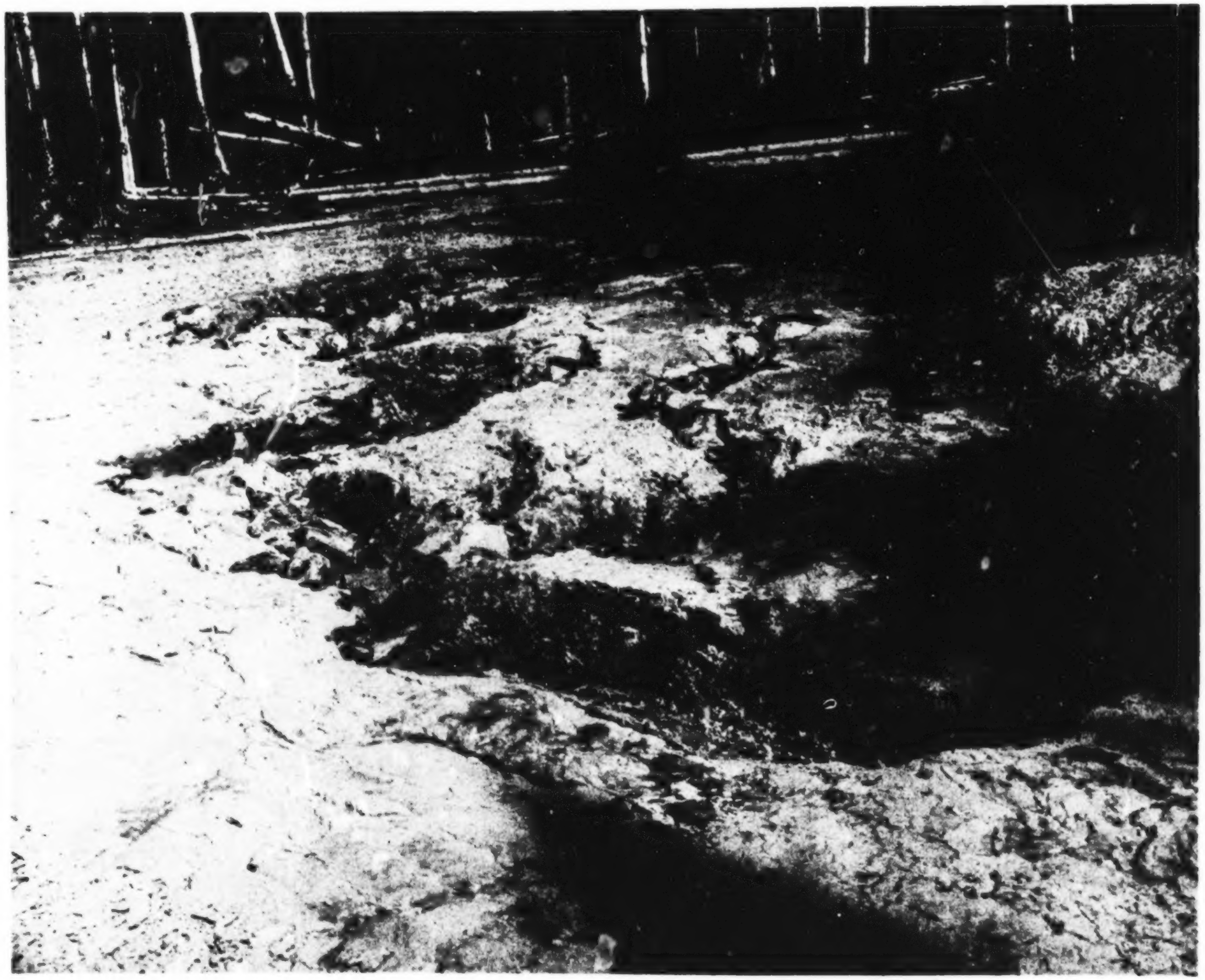

Figure 34. Erosion caused by melt water from spring breakup (1972); some of those gullies are 3-4 feet deep and could have been prevented if drainage had been provided the previous season in anticipation of just such a situation as this.

outside the road prism, except where burning of the debris is necessary to reduce fire hazard, prevent insect infestations, or to improve esthetics.

6. All vegetal mat possible should be left on the edge of the cut. This mat is effective in protecting the cut and improves stability during breakup.

7. Upland materials and existing material sites should be utilized in place of clearwater stream materials if additional road materials are required.

8. Installation of culverts on fish streams should be at low gradient with the bottom of the outlet below the natural streambed to prevent erosion at the downstream end of the culvert.

9. When necessary, because of outfall erosion, an approved stilling basin should be constructed at the downstream end of the culvert. Stabilize the pool sides with riprap or other appropriate material to prevent erosion.

10. Water may be diverted around the work area in the streambed during the installation of the culvert to reduce sedimentation, but only when the diversion would not affect fish passage or spawning. A conduit may be needed to avoid erosion.

11. Water diversion ditches or pumps should be screened with an approved device to prevent harm to migrating fish.

12. Abandoned water diversion structures should be removed, if at all possible, or be plugged and stabilized to prevent trapping fish or impeding fish passage.

13. Erosion control structures, such as water bars, contour furrows, water spreaders, diversion ditches, or gully plugs, should be constructed to avoid induced and accelerated erosion and to lessen the possibility of forming new drainage channels. Control measures should be designed and constructed to minimize disturbance to the thermal equilibrium, thus reducing the adverse effects of permafrost degradation.

14. Unless otherwise approved, temporary access over streambeds should be made through use of fill ramps made of coarse materials, rather than by excavating through stream banks. Such ramps should be removed upon termination of seasonal use or abandonment.

SUPPORT ACTIVITIES

1. The operator should assure that all persons take appropriate measures for the prevention and suppression of fires on right-of-way areas and other lands, and comply with all applicable laws and

regulations and with instructions and directions concerning the prevention and suppression of fires.

2. Area-wide pest control should not be attempted; such action frequently leads to ecological unbalance. Pesticides and herbicides are limited to nonpersistent (such as parathion, malathion, or pyrethrum) and immobile types. When pesticides are used, only those from an approved list should be applied, and then according to Federal, State, and local regulations.

3. Camp wastes of all kinds should be disposed of by approved methods. Effluents from treatment systems should not pollute receiving waters.

4. Petroleum wastes should not be disposed of so that they damage the environment or enter a body of water; these wastes include oil changes, spilled fuel, and antifreeze.

5. Mobile ground equipment should be kept out of water courses, except for crossings within the right-of-way, and then only in a manner that minimizes disturbances.

RESTORATION

1. All slopes should be left in a stable condition.

2. Haul ramps, berms, dikes, and other earthen structures should be leveled unless otherwise directed by the resource manager.

3. Connect material pits in stream and river bottoms and channels to the stream by channels constructed to allow flow of water through the pit, if approved by a fisheries biologist.

4. Vegetation, overburden, and other materials removed from surfaces of borrow and waste sites should be disposed of in an approved manner at termination of use of the site. Chipped vegetative debris can be spread evenly over these sites, together with other organic materials and topsoil. If possible, during construction or immediately following terminal use of the site, the area should be revegetated. A vegetative guide was recently published by the Soil Conservation Service (1972) that recommends seed mixtures for the major climatic zones and soils of Alaska. Seeding on the snow is one procedure that should be considered and used, if feasible, to take advantage of early moisture for seed germination.

5. Upon abandonment or relocation of a campsite, the area should be cleaned up and restored to a condition satisfactory to the regulatory agency.

6. All disturbed areas should be left in a stabilized condition. Stabilization practices may include seeding, planting, mulching, and the placement of mat binders, soil binders, rock or gravel blankets, or structures, as determined by the conditions at the site. Figures 35 and 36 show two stabilization practices.

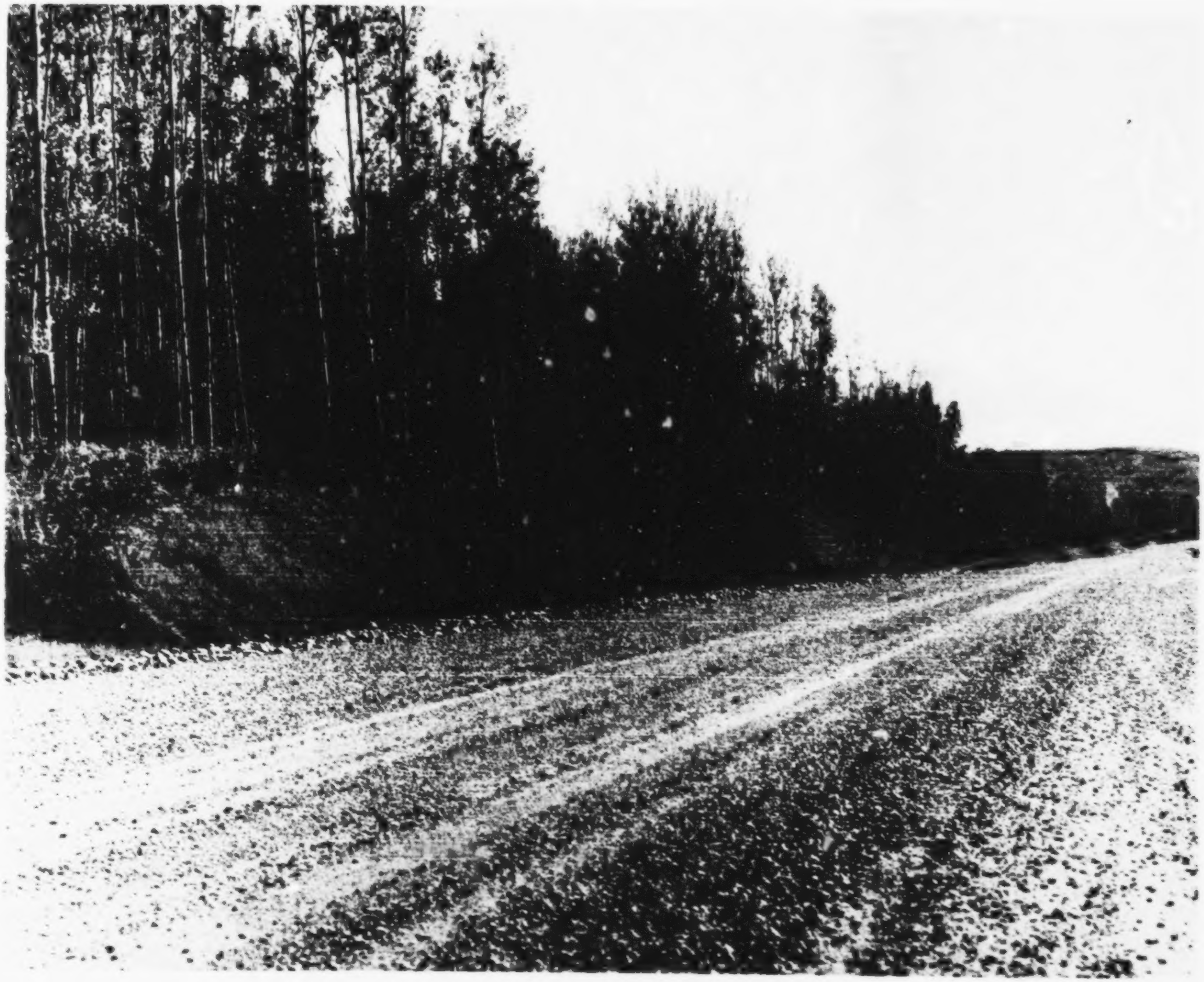

Figure 35. Seeding to stabilize cuts in silty soil. Note the native vegetation overhanging the cut. Road machinery was kept off the right-of-way above the cut, which further tends to stabilize these slopes. Gold Stream Road, 1973.

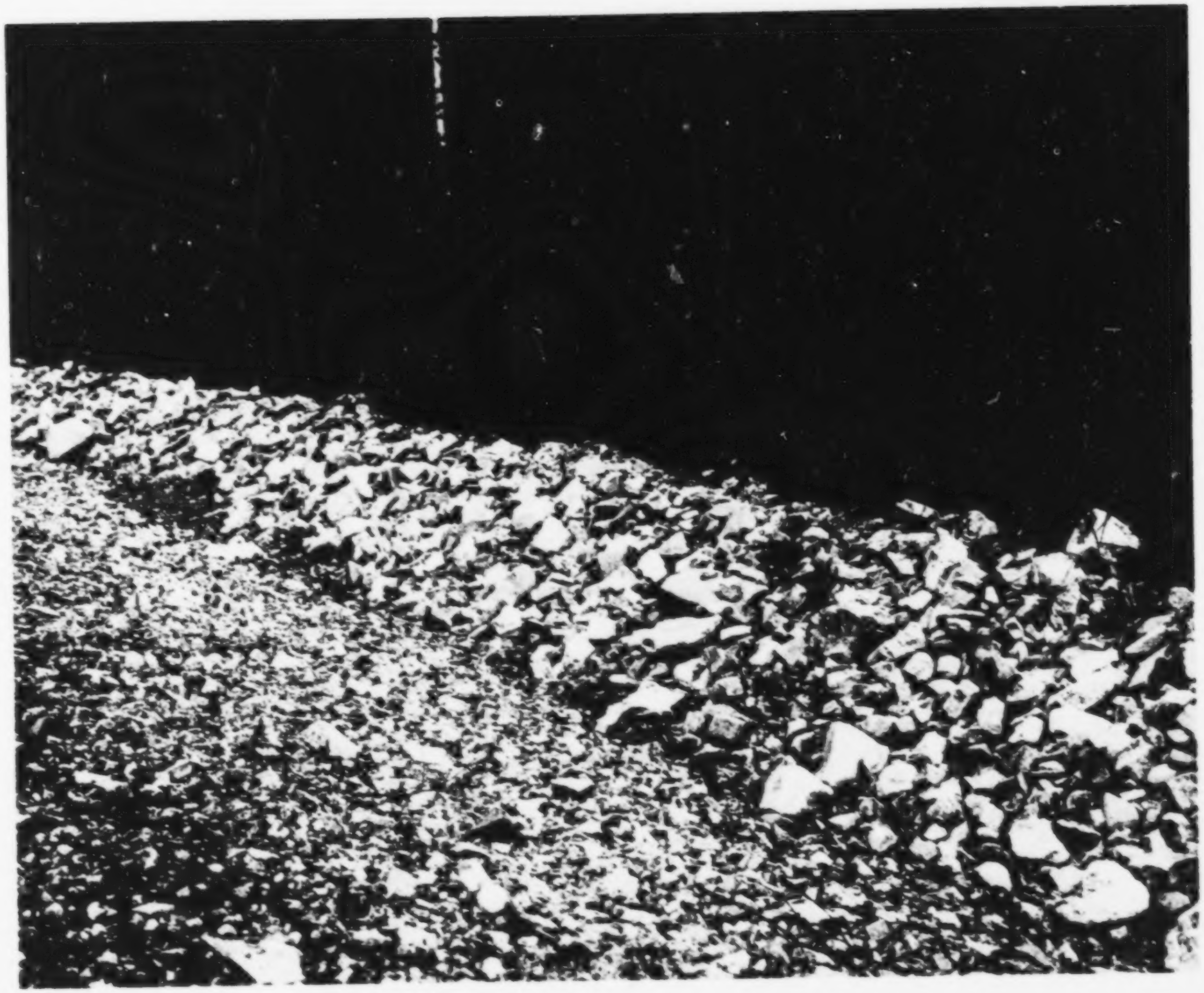

Figure 36. Rock armor in roadside ditches effectively prevents erosion on erodible silt. Note here the sharp line between the rock and the grass-covered silt of the cut; such treatment can be emplaced with road machinery and requires little maintenance. (Gold Stream Road north of Fairbanks)

ROAD MAINTENANCE

Proper maintenance is essential if a road is to remain usable. Long after construction activity ceases, and as long as the road is being used, maintenance must continue in an efficient and timely manner. The accrued maintenance cost may equal or exceed the original cost of construction. These costs can be reduced if the route is well selected and the problem areas are properly handled during design.

Permafrost and long, severe winters cause unusual problems in the subarctic that add to those of road maintenance encountered in milder climates. Seepage zones can cause icings that may build up to several feet if steps are not taken to keep small channels thawed to remove liquid water and prevent it from freezing on the road surface.

Full and thorough maintenance of all portions of the road system is necessary to prevent water quality degradation owing to accelerated erosion during heavy rainstorms. This includes the regular maintenance of drainage diversions, such as cleaning culvert inlets before freezeup and keeping them clean during the rainy season to diminish the danger of clogging and the possibility of washouts. It also includes the inspection of revegetation on obliterated spur roads and reseeding where necessary. As specified above for construction activities, all excavated material should be end-hauled and deposited in safe bench or cove locations well above high-water levels. This material should never be deposited directly into flowing streams. Some additional suggestions are:

1. Spur roads that outslope should be cross-drained and berms on the outside edge removed, except those intentionally constructed for the protection of road grade fills.

2. Outsloped road drainage can be retained by performing proper maintenance grading. This precludes both the undercutting of newly or partially stabilized cut slopes and the leaving of a berm (except for fill protection) along the outside edge of the road, which might concentrate drainage on the road.

3. Extreme caution is necessary in the selection and application of herbicides for controlling brush encroachment along road edges. These chemicals should not be allowed to drift or run off into streams to cause objectionable tastes or odors in the waters or to create adverse conditions for aquatic life or human consumption. Mechanical equipment is preferred to herbicides for control of roadside brush (Figure 37 shows one such unit).

4. Maintenance should be planned and scheduled on a continuous basis for routine work.

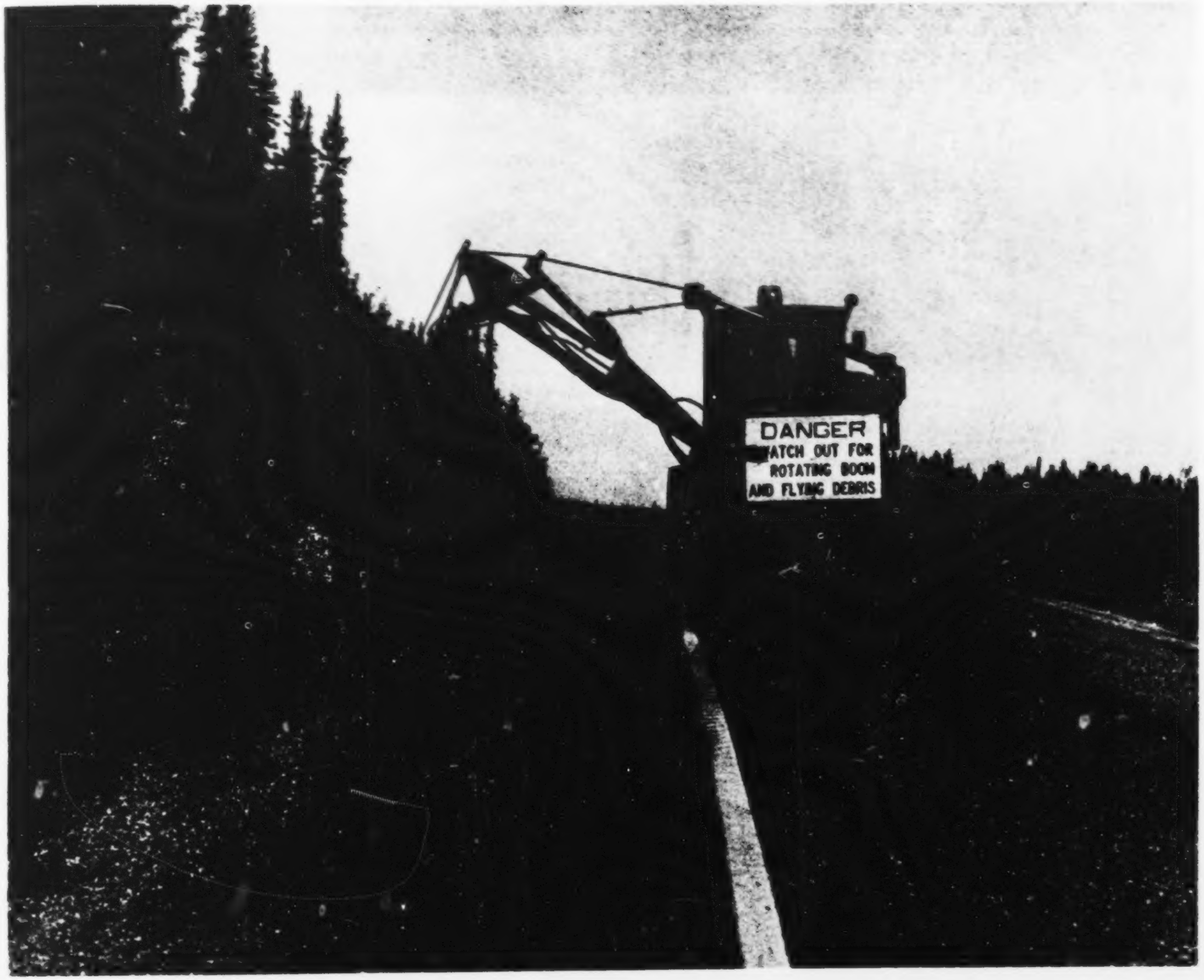
DANGER
WATCH OUT FOR
ROTATING BOOM
AND FLYING DEBRIS

Figure 37. Mechanical clearing along roads by shredding without the need to get into roadside ditches. Such a method improves driving visibility and avoids the need for herbicides.

5. All personnel should be asked to report unusual maintenance needs, such as a new frost boil or sedimented culvert, before it becomes a serious problem.

6. Cuts and fills subject to erosion should be stabilized with vegetation or other material.

7. Stabilized slopes should not be disturbed by maintenance equipment. The road should be kept crowned and free of ridges along the edges to maintain lateral drainage. Material cleared from ditches should not be moved to where it can wash into water courses.

8. Vertical cuts are usually the most stable slope for wind-deposited silts. For these cuts, drainage must be provided and maintained to prevent water from running over the upper edge of the cut banks.

9. On haul roads used in winter, snow berms should be removed before breakup to permit lateral drainage and prevent concentrating water between berms and running down centerlines.

PUTTING ROADS TO BED

The overall management plan for resource development in a particular area determines whether or not roads will be maintained or abandoned (put to bed) (Figure 38). On logging areas, for example, most of the main haul and all spur and skid roads usually will be abandoned and allowed to revert to native vegetation. If roads are put to bed, it may be years before they are again used. A well-planned, properly constructed road system can be cheaply put back into use if certain measures are taken in putting the roads to bed. Because of the long time between abandonment and re-use, many natural materials may rot and be useless when again needed. Therefore, structures using these materials should be removed. Since active erosion prevention measures will no longer be available, utmost care must be taken at this time to provide proper, well-protected drainage and establishment of vegetation on all disturbed areas.

GUIDELINES FOR PUTTING ROADS TO BED

1. All open-top culverts should be removed and sufficient cross-road drainages provided to accomodate runoff at breakup. Culverts placed in natural drainages should also be removed, as their inlets collect debris and gradually plug, resulting in washouts over the road. These drainages can be stabilized with gravel, and native vegetation allowed to establish. Native tree species are quickly re-established, even on old compacted roads, once traffic is eliminated (Figure 39).

2. For several years after abandonment, the road should be inspected immediately after breakup for evidence of erosion. Eroded portions should be repaired immediately to prevent further erosion and sedimentation.

3. Disturbed, bare areas should be seeded with recommended grass species and fertilized with NPK mixture to insure initial quick growth to protect bare soil (Soil Conservation Service 1972).

4. Petroleum products, containers, and abandoned equipment should be removed from landings, service areas, and roadsides before the roads are put to bed.

5. On old haul roads and main skidtrails, special attention should be paid to cross draining at points just above steep sections and to the erodibility of the soil.

6. Vegetative debris is usable to stabilize sections likely to erode after abandonment. Haupt (1959) gives some good recommendations on spacing of drainages when putting roads to bed, and Kidd (1963) does the same for skidtrails.

Figure 38. An area on the Chena River logged by selective cutting. Several haul roads and yarding areas appear in this photo that will probably be "put to bed" and allowed to return to forest. This level terrain should not develop problem areas caused by erosion or thawing; no permafrost is present here.

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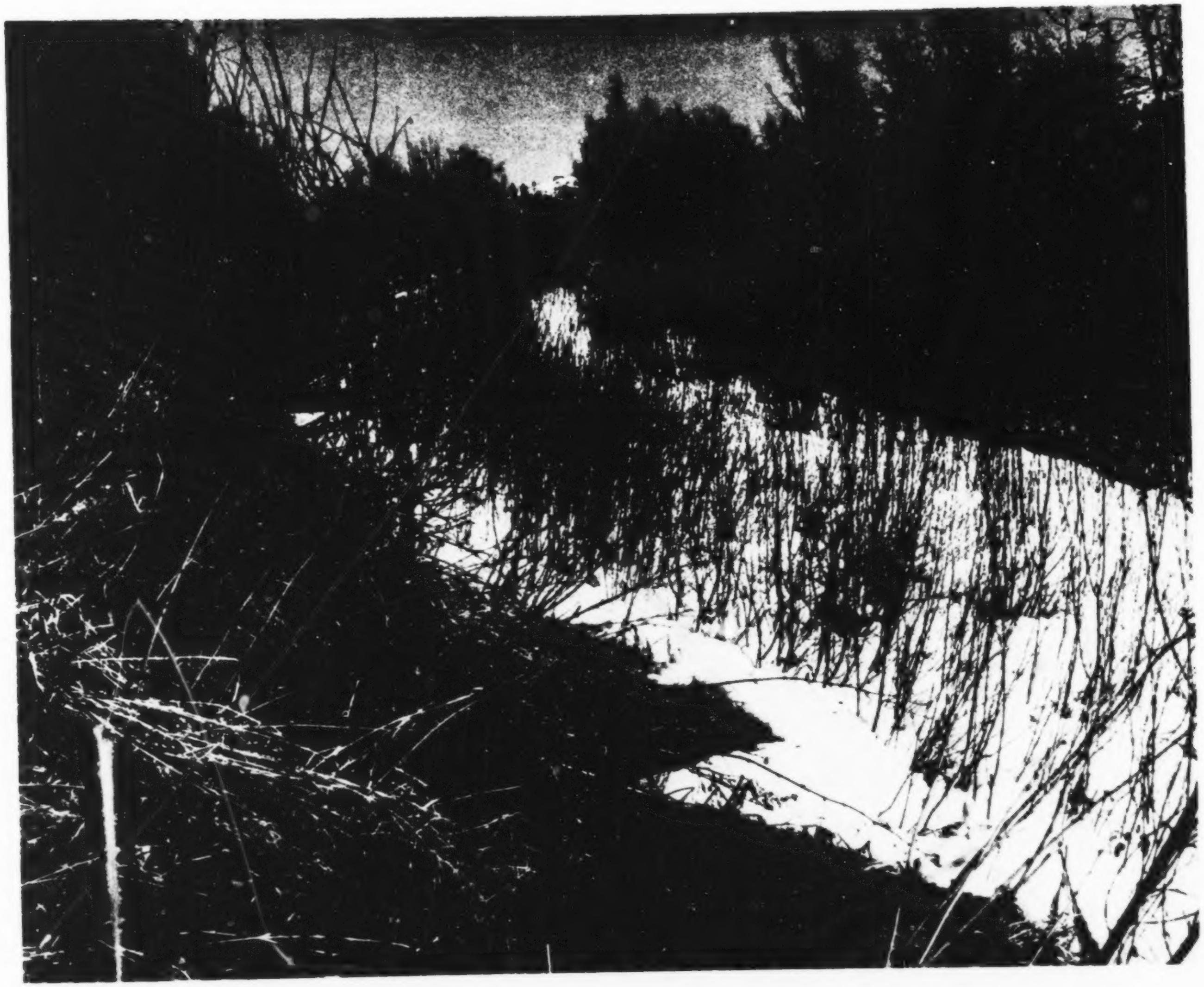

Figure 39. Abandoned roads soon become revegetated even though they were gravel and thoroughly compacted. This photo shows an abandoned portion of the old Steese Highway about a mile west of Cleary Summit, abandoned in 1964. The brush shown here is alder, which appears to be the initial invader of abandoned roads (spring 1973).

ROADS ON MUSKEGS

INTRODUCTION

Muskeg is an organic terrain consisting of living vegetation over peat or plant detritus of any depth over a mineral sublayer. Muskeg is similar to bog, except that the latter is confined to smaller area units.

Many properties of muskeg make customary road designs of limited applicability and must be considered when developing access across these areas. Such properties include vegetation cover, peat depth, type of mineral sublayer, peat structure, peat density, shear strength, peat water content, drainage pattern, permeability, frequency of open water, permafrost, etc. (MacFarlane 1969).

The problems with construction over muskeg are many and may represent severe environmental disturbances. Muskeg, like permafrost, should be avoided wherever possible. This sometimes can be done by adequate planning through on-the-ground exploration and study of aerial photographs. Where muskeg crossing is unavoidable, great care should be taken to construct stable roads compatible with the engineering characteristics of muskeg.

MUSKEG PROPERTIES

On muskeg, the vegetation cover can vary from trees through shrubs, herbs, grasses and sedges, mosses and lichens. Depths may range from 2 or 3 inches to over 80 feet. Structure is a function of the vegetation type that built up the peat; it may range from coarse and fibrous to fine and smooth. The density of saturated peat is about the same as the density of water, with higher densities usually associated with higher inorganic content. Drainage patterns can indicate subsurface topography and the extent to which the muskeg is confined. Open water usually indicates places that must be filled or bridged. Permeability varies widely, but many peat types are relatively impermeable. Construction over frozen muskeg is a special problem and largely one of maintaining thermal stability.

The significance of physical properties in road construction is developed in considerable detail by MacFarlane (1969). Because such detail is beyond the scope of this paper, only some general principles in development road construction over muskeg will be considered.

ROAD CONSTRUCTION

Carbon dating indicates that the oldest known roads in muskeg were built between 4,000 and 4,800 years ago. These were corduroy roadways of planks tied together (MacFarlane 1969). This method of construction is still used today, usually with a soil fill for a smooth surface.

The method of road construction selected depends upon the frequency and weight of traffic. For some purposes, considerable settlement, undulation, and distortion of the roadway can be tolerated. For such low standard roads, the availability and cost of materials such as corduroy, sawdust, gravel, etc., will determine the type of construction.

The most inexpensive method of constructing roads on muskeg and at the same time creating the least environmental disturbance is to float the road directly on top of the vegetation mat if the muskeg is less than about a meter in depth. If the peat exceeds a yard in depth, a corduroy is used over the vegetation mat before laying the road fill.

Right-of-way clearing should be done by hand in order to keep equipment traffic off the muskeg surface. All woody vegetation should be cut off at ground level with the cut material placed as a mat on the surface. Under no circumstances should the surface mat of the muskeg be disturbed (MacFarlane 1969). The fill, preferably sand and gravel, may be placed alone over shallow peat, or over corduroy, brush, sawdust, wire mesh, straw bundles, or dried peat (MacFarlane 1969).

Corduroy is laid with longitudinal stringers, with staggered joints, across which are spiked decking logs. Branches and smaller trees are placed on top of the logs.

Another type of construction is laying the cleared trees side by side (without linking) across the centerline of the road. Small trees and brush make up the next course. In both cases, the mat should be completely covered by fill so that air is excluded. If air is excluded, the mat should remain sound indefinitely (MacFarlane 1969).

Drainageways should not be constructed if drainage can be avoided. If drainage is necessary, it should be planned to create the least possible disturbance to the natural drainage pattern. Lowering the water table will cause deterioration in the structural strength of the natural muskeg mat (MacFarlane 1969).

Embankment of fill should be granular and can be larger than four inches for the base course and up to 3/4 inch for its top course. In southeast Alaska, for heavy loads, logging spurs in muskeg are built up of coarse rock over a corduroy and topped with a surfacing course of finer material. The fill, or embankment, may need to be from 1 1/2 to several feet thick, according to traffic demands.

In frozen muskeg or permafrost areas, the road design is based on preserving the frozen state (MacFarlane 1969). Right-of-way clearing should barely precede the fill, and the fill should be up to 6 feet thick to maintain the permafrost.

Perhaps the simplest way to deal with muskegs is to use light-duty, winter haul roads. Vegetation is cleared to prepare a surface that is easily leveled once freezing has started. Hand clearing creates the least disturbance to the surface mat. However, dozing is sometimes done after freeze-up and in the season before the road will be used. Harrison (1955) reported that the uneven surface will partially "settle down" during the summer. The greatest depth of freezing is obtained by removing or packing the snow cover. It has been reported (Harrison 1955) that even snowshoeing is helpful, followed by snowmobiles packing until the freeze depth is enough to support heavier equipment for smoothing the road surface.

ICE BRIDGES

During winter operations in valley bottoms, it is frequently necessary to cross over the stream ice which, to be reliable, should be strengthened by ice bridging. Ice 4 to 6 feet thick will support heavy loads that continue to move, but tends to deform and crack under static loads. Army tanks crossed the Imkin River in Korea on a total ice thickness of only 20 inches with timber pads under the tracks, so it is apparent that ice freshly frozen is amply strong to carry moving loads.

Although many ice bridges include timber, limbs, and other materials, there is another philosophy which reasons that proper construction of an ice bridge without extraneous materials gives adequate strength. It is generally agreed that the ice at crossings must be strengthened by building up natural ice in broad, thin layers. Some say that additional materials only add to the total work and cost and do not contribute additional strength. Prior to pumping water over the ice to freeze, all snow should be removed from the crossing, which permits thicker ice naturally because of the absence of insulating snow.

In building the 1,500-ft. ice bridges across the Yukon River in the winter of 1969-1970, a part of the Hickel Highway, the Alaska State Highway Department used logs as reinforcing material before pumping water to thicken the ice. Prior to laying the log materials, snow was bulldozed into berms parallel to the road to expose clear ice. This permitted deeper freezing and also helped to contain water that was pumped onto the road to thicken the ice containing the reinforcing log network. Water was added in thin layers to prevent cavities that form if thick layers are pumped into place. The final ice thickness was 5 feet. Instead of raising the roadway as the ice thickness increased, the added ice thickness "flowed" downward and the roadway was level with the nearby thinner ice that had formed naturally. After the Yukon ice bridge was completed, the river stage dropped almost 5 feet, yet the bridge remained solid and supported loads as high as 100 tons on a single truck, semi-trailer unit. It is thought that the reinforcing timber contained in this bridge did in fact prevent its failure when the water level dropped.

Because a relatively large quantity of timber was used on the Yukon, it was thought that, at breakup, this mass of floating timber would cause jams downstream. However, most of the bridge melted before breakup, releasing the timber, which gradually floated away above the ice, and no jams were caused. Figures 40, 41, and 42 show the Yukon ice bridge at various stages of construction and clearly demonstrate that a large volume of timber went into its structure.

The ice bridge built across the Yukon in 1973-74 used ice built up in thin layers, without reinforcing timber. If the water is pumped in thin increments, there is no need to confine it, because it freezes

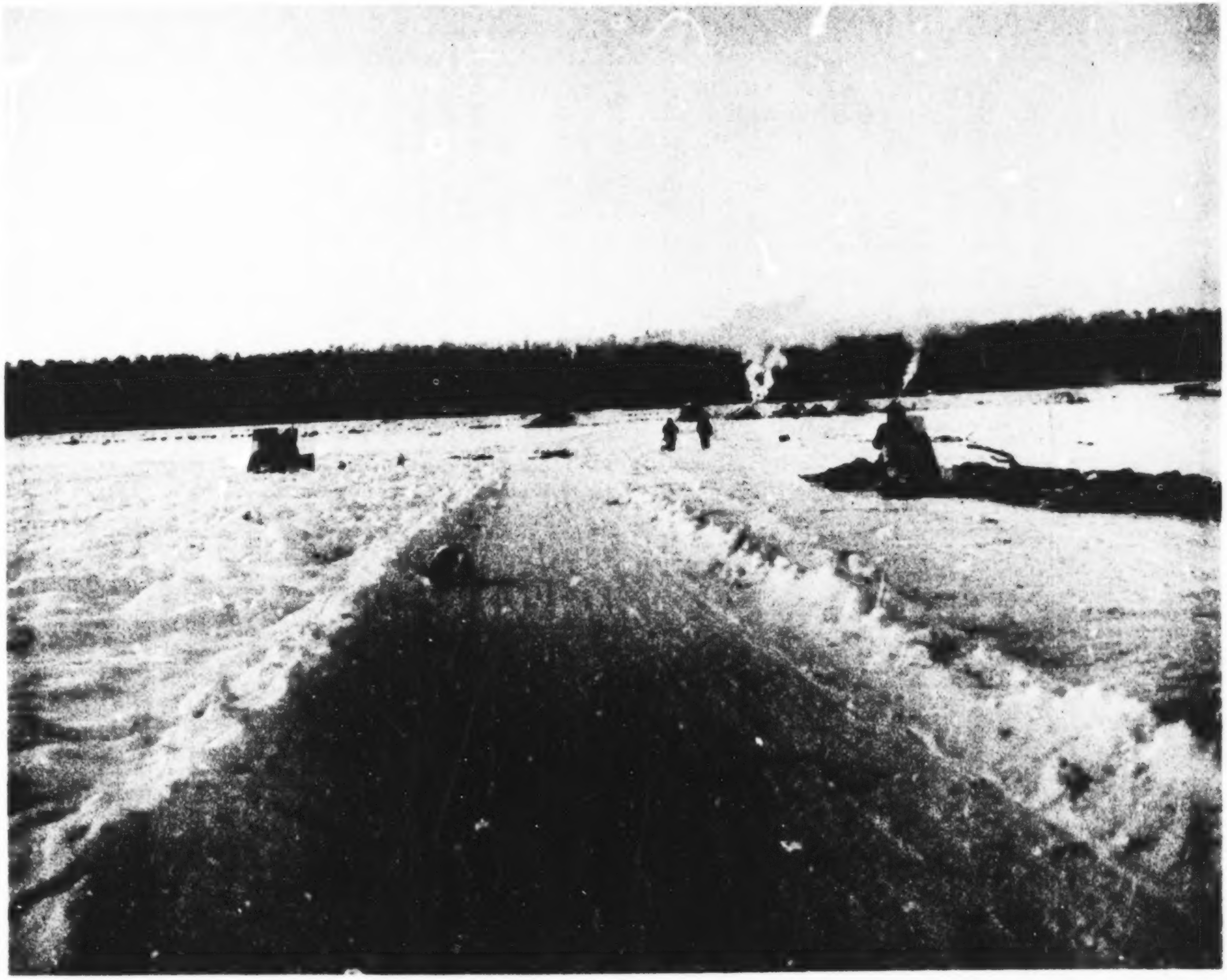

Figure 40. Yukon River ice bridge site (1969) in the early stages of construction. Timber from the nearby forest is being brought in by snow machine and a narrow strip across the river has been bladed free of snow. This strip was later widened with a small bulldozer into berms parallel to the road. Stripping off the snow permits thicker ice to form. (Photos in Figures 40-42 courtesy of Fairbanks Daily News-Miner)

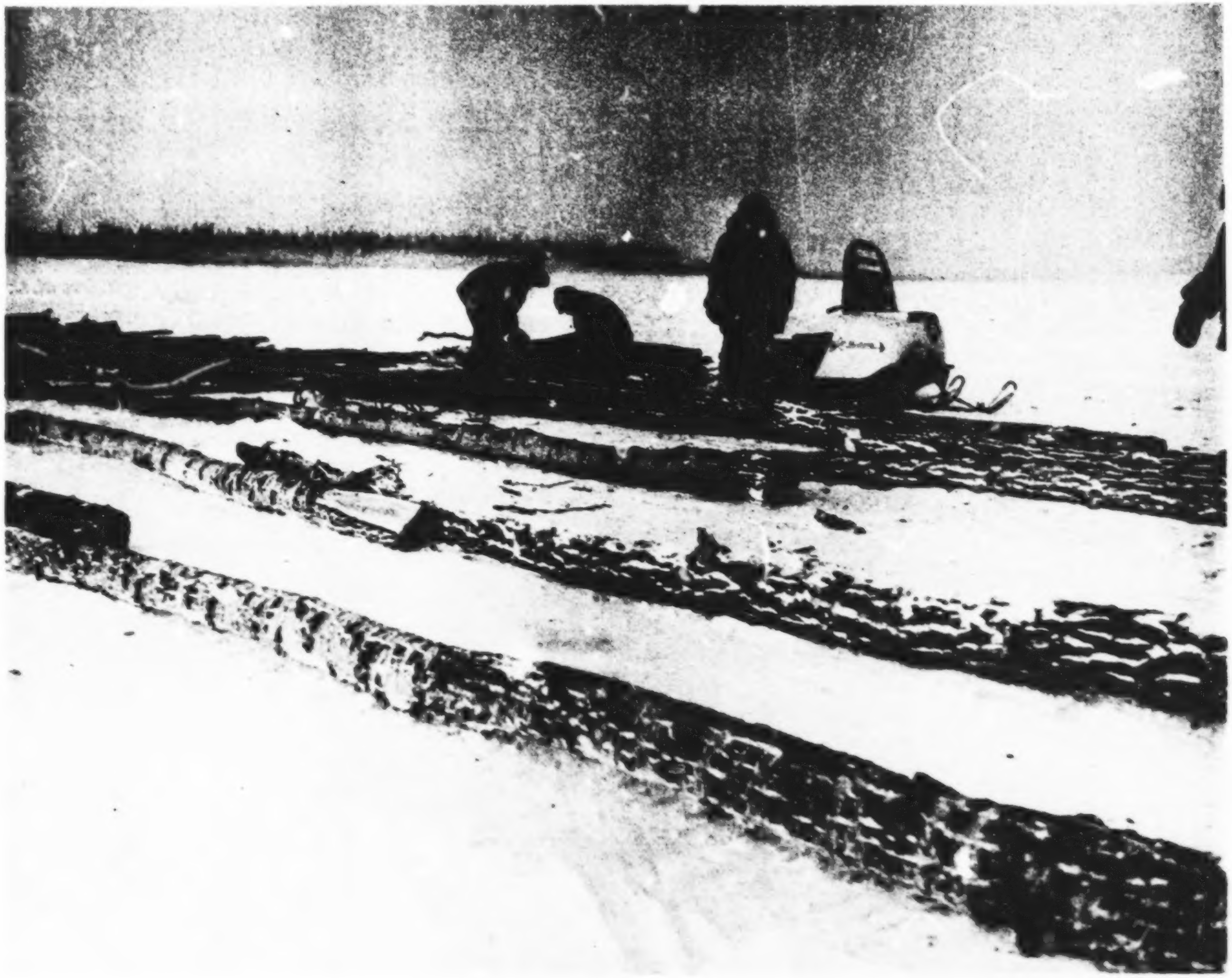

Figure 41. Timber reinforcement being placed: First large stringers are placed parallel to the roadway several feet apart, followed by closely spaced cross timbers. This crossing was 1,500 feet long and took 4-6 weeks to build. Labor was provided by the natives of Stevens Village, located near the site of the crossing.

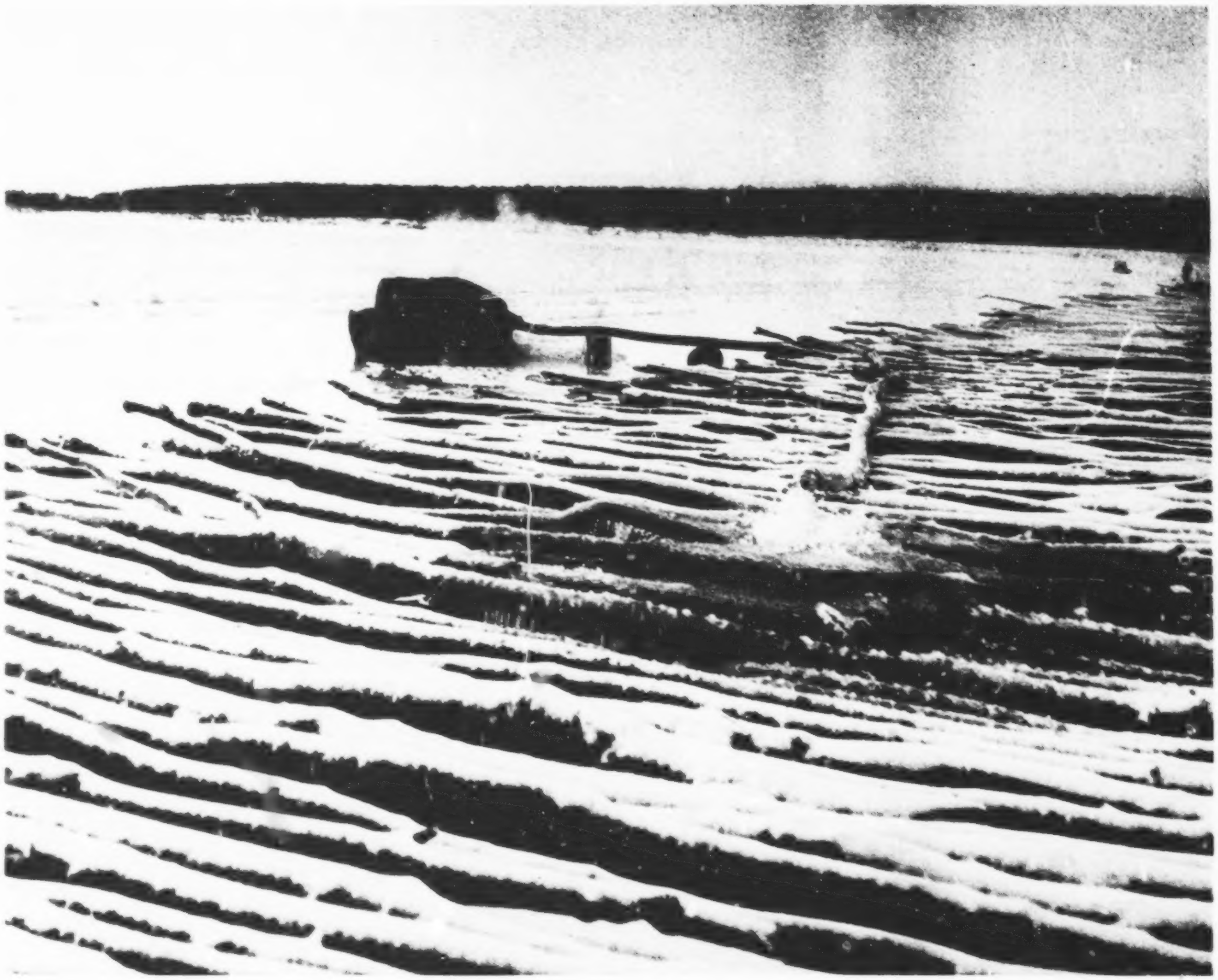

Figure 42. Pumping water from under the ice in thin increments to give a total ice thickness of 5 feet. All timbers were solidly cemented in place as the water froze. Temperatures during these operations ranged from 50°-70° below zero

rapidly during cold weather. What is desired is a broad expanse of thickened ice whose cross-section is similar to a convex lens. Hughes (1960) cites some experiences using outboard motors as pumps to thicken ice in Canada that should apply equally well for Alaska. Not using extraneous materials in the bridge avoids the introduction of debris when the bridge melts during spring breakup.

Whether or not reinforcing material is used, several suggestions are offered for the construction of ice bridges. Snow should be removed from the roadway, allowing quicker, deeper freezing. If the ice thickness is increased by pumping water, water should be added in thin layers to prevent formation of cavities, which weaken the ice. An un-reinforced bridge should not be used if the water is not in contact with the ice. Heavy loads should not be allowed to remain stationary on an ice bridge; Breakage of ice has been experienced under parked planes. If the load continues to move, the ice supported by water does not deform and will continue to support the load.

REFERENCES

1. Burns, J. W. Some Effects of Logging and Associated Road Construction on Northern California Streams. Transactions of American Fisheries Society. 101:1-17. 1972.

   The research reported here, although done in California, clearly demonstrates that most damage is caused by logging road construction and can be materially reduced by employing recommended procedures during road construction and skid road layout.

2. Federal Water Pollution Control Administration (FWPCA). Industrial Waste Guide on Logging Practices. Portland, Oregon. 79 p. February 1970.

   Although this guide deals with forests of the Northwest, many recommendations apply equally well to Alaska.

3. Forest Service. A Research and Development Program for Advanced Logging Systems (FALCON). U. S. Department of Agriculture, Forest Service. 1972.

   This pamphlet is included to indicate some new trends in Forestry, Advanced Logging and CONservation and considers such innovations as balloon and helicopter logging, among others.

4. Harrison, W. C. Primary and Secondary Access over Muskeg in Forestry Practice. Proceedings of the Western Muskeg Resource Meeting. National Research Council of Canada, Technical Memorandum No. 38, p. 6-13. 1955.

5. Haupt, H. F. A Method for Controlling Sediment from Logging Roads. USDA Forest Service Miscellaneous Publication No. 22. 22 p. 1959.

   Engineering and other technical data are presented that should be helpful to any operator planning logging roads.

6. Haussman, R. F. Permanent Logging Roads for Better Woodlot Management. USDA Forest Service, Northeast Region, Division of State and Private Forestry. 1960.

   Although directed at small operations far from Alaska, this bulletin contains many sound recommendations on design and construction that are useful everywhere.

7. Hughes, J. R. The Outboard Motor--the New Ice-Making Machine. Canadian Pulp & Paper Association, Woodlands Section, Index No. 1949 (B-10), p. 1-5. 1949.

Hughes describes the use of small outboard motors (10 hp) as efficient means of pumping and spreading large volumes of water to thicken ice and provide sufficient strength to support heavy loads.

8. Hutchison, O. K. Alaska's Forest Resource. USDA Forest Service Resource Bulletin PNW-19. 74 p. 1968.

The most accurate and up-to-date appraisal of forest resources of Alaska. Interior forests are well covered.

9. Kay, A. R. and Lewis, R. B. Passage of Anadromous Fish through Highway Drainage Structures. State of California, Division of Highways, Highway Research Report No. 629110. June 1970.

Concludes that properly built drainage structures do not interfere with fish passage, presents technical data for design.

10. Kidd, W. J., Jr. Soil Erosion Control Structures on Skidtrails. USDA Forest Service Research Paper INT-1. 8 p. 1963.

Presents many design considerations on controlling sediments derived from skidtrails; most recommendations are applicable in Alaska.

11. Lantz, R. L. Guidelines for Stream Protection in Logging Operations. Oregon State Game Commission, Report of Research Division. 1971.

This excellent report not only presents a good set of guidelines to protect streams, but also gives a brief description of principles and rationale of biological needs for protection; based on research done recently in western Oregon but applicable in Alaska.

12. Lotspeich, F. B. Environmental Guidelines for Road Construction in Alaska. Environmental Protection Agency, Alaska Water Laboratory, College, Ak. Report No. 1610-Fol, 127 p. August 1971.

Presents the environmental need for controlling sedimentation during road building, how National Environmental Policy Act is influencing new concepts, and offers recommendations for protection during the road building cycles. Includes photos illustrating good and bad examples.

13. MacFarlane, I. C. Muskeg Engineering Handbook. Division of Building Research, National Research Council of Canada, Canadian Building Series No. 3. University of Toronto Press. 297 p. 1969.

14. Metsker, H. E. Fish Versus Culverts: Some Considerations for Resource Managers. USDA Forest Service Engineering Technical Report ETR-7700-5. July 1970.

Gives a good review of biological requirements for well functioning culverts and why certain conditions must be fulfilled if fish are to pass through culverts.

15. Murchison, H. G. Preliminary Studies of An Air-Cushion Vehicle for Logging in Eastern Canada. In Proceedings of 14th Muskeg Research Conference. May 1971.

The vehicle described in this paper is an example innovation to harvest trees in areas of boggy ground and permafrost without disturbance; such a vehicle could well be used in Alaska, where logging must be done where it is essential to cross permafrost areas in summer.

16. Packer, P. E. and Christensen, G. F. Guides for Controlling Sediment from Secondary Logging Roads. USDA Forest Service, Intermountain Forest and Range Experiment Station. [n.d.]

This pocket-size guide is packed with useful information that can be carried in the field by anyone involved with logging roads and summarizes the results of extensive research on sediment control.

17. Pearce, J. K. Forest Engineering Handbook. U. S. Department of the Interior, Bureau of Land Management, Oregon State Office. June 1961.

This handbook was prepared under a contract with BLM and contains a wealth of engineering information on all phases of logging in the Pacific Northwest. Many principles are just as applicable to the Alaskan scene with suitable modifications for environmental differences.

18. Soil Conservation Service. A Vegetative Guide for Alaska. Report No. M7-N-22612. 50 p. 1972.

19. U. S. Army Corps of Engineers. Environmental Protection Measures for Construction Operations. Seattle, Wa. March 1971.

This pamphlet presents protective measures through line drawings directed at the individual equipment operators, showing how each can contribute to environmental protection.

20. Woodworth, J. R. Statement of Policy Concerning Facilities at Culvert Installations. State of Idaho, Idaho Fish and Game Department. August 1967.

This brief policy statement makes specific recommendations for culvert installation to fit Idaho conditions, many of which are similar to those of interior Alaska, with the aim of protecting the fisheries.